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THE SOUTH STAFFORDSHIRE INSTITUTE
OF IRON & STEEL WORKS' MANAGERS.

PROCEEDINGS.

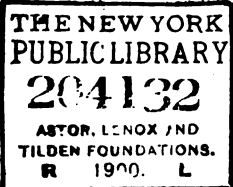
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# **THE SOUTH STAFFORDSHIRE INSTITUTE OF IRON & STEEL WORKS' MANAGERS.**

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**SESSION 1898—1899.**

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The first Meeting of the Session was held at The Institute, Dudley, on Saturday, December 10th, 1898.

Mr. H. LE NEVE FOSTER (President) occupied the chair.

The minutes of the last Annual Meeting were read, adopted, and signed.

Messrs. W. H. Venables, John Harley, W. J. Foster, R. W. Bradley, Walter Jones, W. H. Richards, and Geo. W. Summers were elected members of the Institute.

Mr. HORACE ALLEN was then introduced and read the following paper :—

## THE BLAST FURNACE AS A SOURCE OF POWER.

By HORACE ALLEN, C.E.

### THE BLAST FURNACE.

Probably no monument of human industry possesses as many features of interest to man as does the ironmaking blast furnace. Even its proportions, considered alone, in their colossal dimensions are impressive.

#### A SYMBOL OF INDUSTRIAL PROGRESS.

The erection of blast furnaces may be said to be the most conspicuous landmark, to illustrate the progress of the industrial history of every modern manufacturing country; and if one desired to determine the comparative position in the scale of industrial supremacy of any given nation, an interrogation as to the yearly output of its blast furnaces would, in the answer given, provide all the data for comparison.

#### THE COMPARATIVE CONSERVATISM OF PIG IRON MAKING.

The changes of procedure in the actual operations of ironmaking have not been great. The modern process of separating iron from its oxide, or earthy associate, is practically identical with the operation of earlier days when the windmill and the water wheel were the only sources of motive power. The operation then, as now, consisted in surrounding iron oxide ore, or ironstone, with a strong reducing environment in combination with a temperature that would melt the iron produced.

#### THE ELEMENT OF CHEMICAL REDUCTION.

Carbon has always been the reducing agent, and the only change that has come in the employment of this agent is in the physical form in which it is used. Originally charcoal, it has, to a large extent, been replaced with coke, the alternative agent being hard bituminous coal in Scotland, and anthracite in the United States. Charcoal is still employed in countries where it is found to be economically accessible.

The separation of the earthy matter from the reduced, carburised, and melted iron is effected by the introduction of a flux that forms, in combination with the earthy matter, a fusible slag of a lighter specific gravity than the iron itself, and which is therefore easily separated from the molten metal.

The carbonaceous reducing environment of the ore produces a gas, that still issues from the mouths of many blast furnaces, and provides a

. . . . .

strange and lurid beacon that can be seen for miles, and seen issuing from the many furnaces of the "black country" of England, produces a strange and eerie effect that is clearly impressed upon one in many of the pages of Dickens' "Old Curiosity Shop."

Not many years ago the great tongues of flame issuing from the mouths of the Scottish furnaces constituted the only artificial illumination for a district of Glasgow, and "Dulap's" furnaces had no little influence in creating that vigorous centre, forming the industrial heart of Lanarkshire. The great beacons must have been, indeed, inspiring to have prompted the exercise of poetic genius, to express the gratitude flowing along the lines of the stanza,

"We are muckle obleeged to you, Colin Dulap.  
You're really a worthy old patriot chap  
Tae enlighten the country sae, Colin Dulap."

This acknowledgment was probably the only return that Colin Dulap obtained from the great lights of his furnaces.

#### THE STAGES IN THE EVOLUTION OF THE MODERN FURNACE.

The introduction of hot instead of cold blast put out the light that had inspired poetic effort. The saving from the Neilson hot blast system, perfected by Cowper, Whitwell, Crook, and others, has culminated in the reduction of the fuel consumption to a figure that is less than one-third its former proportion, until now it merely equals the weight of the iron produced.

Another step in the line of economic progress, made some thirty years back, was to utilise a part of the waste blast furnace gases in the flues of steam boilers. More recently the scene of experiment in blast furnace practice has been removed to the United States, and the plant at Duquesne, in Pennsylvania, contains, in its gigantic equipment, many improvements of detail that have led to a cost of production, that is, in its possibility of economic rivalry at the place of manufacture, quite above the plane of European competition. It may be mentioned, in passing, that in a few of the blast furnace installations, and those of a coal fed character, some economy has been secured by the separation of the nitrogen in the form of ammonia from the escaping gases.

It has already been stated that blast furnace gas has been employed for steam generating purposes, but the most eminent ironmasters, and with some reason, thought that this gas would burn only at atmospheric pressure, and in large volumes under the influence of continuous combustion. They knew that even under these favourable conditions the gas could not always be maintained in a state of ignition in steam boiler furnaces—so that when, some four years ago, Mr. Thwaite brought his system before the immediate notice of ironmasters, they simply ridiculed the idea that gas, that would fail occasionally to light in large volumes in the flues of steam boilers, would enflame with the extreme rapidity

required in the water-cooled cylinder of a gas engine. A pioneer must ever be accustomed to ridicule. He has the consolation of knowing, that he who laughs last, laughs longest.

#### THE PIONEER INSTALLATION IN SCOTLAND.

The Thwaite system was, strangely enough, practically initiated not far away from the district once lighted by famous Colin Dulap, and the system has been practically in constant operation since the end of 1895. In this plant (Figs. 1 and 2), erected by the Glasgow Iron Company, the engine has been engaged constantly for over three years in driving the electric light machinery of the works, and, but for the death of the proprietor, would before this have been driving part of the iron and steel works' machinery as well; but this development of the application has been merely postponed. Mr. James Riley, the general manager of the Glasgow Iron Co., and to whom metallurgy owes a debt that will probably never be amply repaid, referred to the system in the following terms, in a letter dated October, 1896, addressed to Mr. Thwaite :—

“ We have now had a lengthened experience of your method of cleansing and using blast furnace gases in gas engines. We have had a remarkable absence of troubles, and I am pleased to say that the system has fulfilled all you promised and all I hoped, and I hope you will find in the future an adequate return for the valuable process you have worked out.”

#### SOME PRACTICAL CONSIDERATIONS ASSOCIATED WITH THE SUBJECT.

When presenting this utilisation of the so-called “ waste gases ” from blast furnaces to those in whose department the effect of the economy will be most felt, many questions will naturally occur to the mind.

Probably the first consideration will be the quality of the gases.

Considering this as an important question, it may be as well to go into this matter rather fully.

The analyses of the gases issuing from blast furnaces in different districts show more or less variety in the quality, in regard to the combustibility of the gas, and therefore it may occur to some managers that the gas from their furnaces, owing to its low combustible proportion, will not be available for use by means of gas engines. The quality of the gases, therefore, becomes an important consideration.

All blast furnace managers will readily understand that when the fuel employed in the blast furnaces consists of coal, or when coal is employed in admixture with coke, that the volatile portion of the coal, consisting as it does of more or less combustible gas, will render the effluent gases richer in combustible matter than when coke only is the fuel employed.

The analyses given will fully bear out this conclusion, and when it is shown that the gases issuing from furnaces using coke only can be

successfully employed in the gas engine, it will go without question, that where a certain amount of coal is used in the charge the effluent gases are available for power purposes by means of the gas engine.

Turning now to the quality of the gases issuing from coke fed furnaces, in some cases already the gases have been used explosively in gas engines, it will be interesting to ascertain if under any circumstances of working, or economy, the gas can become so poor as not to be available as an explosive agent.

The poorest quality of gas that the author has had the opportunity of considering contains 25 per cent. of carbonic oxide, and it is found that this, with its accompanying but small proportion of hydrogen derived from the decomposition of the moisture in the air blast, is capable of giving the necessary explosive force in a gas engine, providing that the amount of compression of the mixed air and gas has been carried sufficiently high.

This is very reassuring, and from it we know that under no circumstances of the working of the furnace can the gas become so poor in combustible as not to be capable of developing explosive power sufficient to develop power in a gas engine cylinder.

This is equivalent to saying that, with a properly designed gas engine, capable of developing power by means of the effluent gases from one or more furnaces, providing the supply of gas is continuous, the conditions of working of the furnace will in no case be such as to render the gas too poor in combustible to continue to drive the engine.

So far, the circumstances are very different to those where a gas producer is employed, for neglect in stoking and irregular working of the producer will result in the gas becoming so poor as to be incapable of being exploded in the cylinder, and therefore the engine may be brought to a stand.

#### THE VOLUME OF GAS PRODUCED PER TON OF FUEL FED INTO THE FURNACE.

The volumetric quantity of gas, or the number of cubic feet given off per ton of fuel consumed in the blast furnace cannot readily be ascertained by measurement, but it can be computed from the analysis of the effluent gas.

The estimation of the volume of gas has been made by not a few chemists, and it involves rather a long and elaborate calculation, and one that would be tedious and not of much value, if introduced here as a constituent to this paper.

It has been estimated that when raw coal is the fuel employed in the furnace, there will be about 130,000 cubic feet of gas evolved for each ton of coal charged into the furnace.

When coke is the fuel used, the quantity of gas is much larger,

amounting to from 170,000 to 180,000 cubic feet per ton of coke charged. Of course, when a mixture of coal and coke is employed, then the quantity of cubic feet of gas will be somewhere between these quantities.

Perhaps the most important consideration will be the volume of gas at any particular ironworks which may be available for use for power purposes. In most of the best arranged ironworks in this country, it is considered that the whole of the effluent gases are turned to the fullest account, by utilising them for,

- I. Heating the hot blast stoves.
- II. Generating steam under boilers, for actuating the machinery of the works.

This is true to a certain and limited extent, but when we take into consideration the difference in the number of cubic feet of gas necessary when burnt in the flue of a boiler to produce the effect of evolving an indicated horse power hour in a steam engine, and that required to produce the same power by means of a gas engine, the economy of substituting gas engines for boilers and steam engines becomes a very serious consideration.

#### THE ECONOMIC ADVANTAGE OF THE NEW SYSTEM.

It may be taken that to produce the power of one indicated horse power by means of boilers and steam engines, even under favourable conditions, requires from 600 to 700 cubic feet of gas evolved from coke fed furnaces, while from 100 to 150 cubic feet, when used explosively in a gas engine cylinder, will generate the same power. The ratio in favour of the new system is thus:—

$$\begin{array}{r} 600 - 700 \\ \hline 100 - 150 \end{array} \quad \text{or nearly}$$

six to one in favour of the new power system.

#### THE CHEMICAL CONSIDERATIONS INVOLVED.

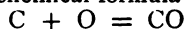
The synthetical determination of the quality or chemical composition of blast furnace gas involves also the determination of the volume or weight of gas produced per ton of fuel consumed in the blast furnace, and this volume or weight is further controlled by the weight of iron ore reduced by a given weight of fuel, besides being affected by the weight of flux employed.

It may be taken, however, that the whole of the carbon entering the mouth of the furnace, with the exception of an indefinite quantity carried out of the furnace by the reaction of  $\text{CO}_2 + \text{C} = 2\text{CO}$  (carbonic acid formed in such conditions that it combines with carbon of the coke and becomes carbonic oxide), is burned to carbonic oxide by combination with the oxygen of the air blast.

As coke is the most general class of fuel employed in blast furnaces, it will be sufficient to only consider this material in the following calculations.

Assuming that the coke contains 90% of carbon, one ton of fuel would be equivalent to 2,016 lbs. of carbon.

If this weight of carbon reached the neighbourhood of the tuyeres it would be converted into carbonic oxide, and the combination would be according to the following chemical formula :—



$$12 + 16 = 28$$

therefore, if 12 parts of carbon give 28 parts by weights of carbonic oxide, 2,016lbs. of carbon would give 4,704lbs. of carbonic oxide.

Calculable illustration :—

$$\begin{array}{r} 4,704 \\ 2,016 \\ \hline \end{array}$$

2,688 Oxygen is accompanied by 8,999 parts of nitrogen.

$$\therefore 23 : 2688 :: 77 : 8999$$

$$\begin{array}{r} 4704 \\ 8999 \\ \hline \end{array}$$

13703 lbs. of gases.

| Allocation | { CO<br>N | 4704<br>8999 |  | Per cent.<br>by Weight. |
|------------|-----------|--------------|--|-------------------------|
|            |           |              |  | 34'33<br>65'67          |
|            |           | <u>13703</u> |  | <u>100'00</u>           |
| By Volume  |           |              |  |                         |
|            |           |              |  | Per Cent.<br>by Volume. |
|            |           |              |  | 34'33                   |
|            |           |              |  | 65'67                   |
|            |           | <u>7'142</u> |  | <u>100'00</u>           |

By the reactions in the blast furnace a certain amount of the carbon is precipitated and is absorbed by the iron, and in the reduction of the ore the oxygen of the ore is taken into the gas, converting the CO into CO<sub>2</sub> but without affecting the relative *volume* of the nitrogen present.

#### AN INVESTIGATION INTO THE CHEMICAL CHARACTER OF THE GASEOUS EFFLUENT.

The desirability of a thorough investigation into the quality of the effluent gases as they leave the top of the furnace, and the necessity of ascertaining whether the common irregularity of the combustion of the gas at the steam boilers is due to the thermal quality or some other cause, is obvious.

### THE DETERMINATION OF THE POOREST QUALITY OF EFFLUENT B. F. GAS.

The object in the following calculations is to arrive at the chemical composition and thermal value of the best and poorest possible qualities of blast furnace gas, and to do this we are assuming 1st, a case where only coke is being charged and no iron made, and 2nd, where 17 cwt. of coke, containing 90% carbon, and 10 cwt. of flux, i.e., limestone, are consumed in the production of one ton of pig iron, having a composition as follows :—

|                  |       |
|------------------|-------|
| Iron.....        | 94'0  |
| Carbon .....     | 4'0   |
| Silicon, &c..... | 2'0   |
| <hr/>            |       |
|                  | 100'0 |

In the case of a blast furnace being charged with coke only, and not producing iron, all the air blast entering the tuyeres would have the whole of its oxygen chemically combined with the carbon of the coke to a state of carbonic oxide, and this carbonic oxide would be accompanied by the nitrogen originally associated with the oxygen, as well as a proportion of hydrogen due to the decomposition of the moisture usually present in the atmosphere, besides and in addition to a small proportion of hydrogen from the coke.

The chemical composition of the atmosphere, by weight, may be taken at :—

|                                |              |
|--------------------------------|--------------|
|                                | Per cent.    |
| Oxygen O .....                 | 22'83        |
| Moisture H <sub>2</sub> O..... | 75 = H = '08 |
| Nitrogen .....                 | 76'42        |
| <hr/>                          |              |
|                                | 100'00       |

The gases resulting from the combustion of the carbon with the air blast have the composition as shown below :—

|                       |   |              |         |                         |
|-----------------------|---|--------------|---------|-------------------------|
| O 22'83               | + | C 17'12 = CO | 39'950  | Per cent.<br>by Weight. |
| H '08 (H in the coke) |   | '047 = H     | '127    | 34'29                   |
| N 76'42               |   | N            | 76'420  | '10                     |
|                       |   |              | <hr/>   | 65'61                   |
|                       |   |              | 116'497 | 100'00                  |
|                       |   |              | <hr/>   |                         |

The percentage composition by volume of this gas would be :—

|                    |        |                                                                                                                                                           |
|--------------------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Carbonic Oxide ... | 33'84  | } The weight of gas produced by the combustion of one ton of coke would equal 13,734'4 lbs., equal to 188,142 cub. ft. at 60° F. One cub. ft. = '073 lbs. |
| Hydrogen ...       | 1'38   |                                                                                                                                                           |
| Nitrogen ...       | 64'78  |                                                                                                                                                           |
|                    | <hr/>  |                                                                                                                                                           |
|                    | 100'00 |                                                                                                                                                           |

The thermal value per cubic foot, at 60°F. down to 212°F. = 121.84 British Thermal units. And this is the richest gas capable of being given off by a blast furnace charged with coke only, as though it were a gas producer.

With a given class of ore and fuel, the poorest quality of gas, in regard to its thermal value, will be produced when the blast furnace conditions are such that the proportion of fuel consumed to the oxide of iron reduced is smallest, and it certainly is very seldom that one ton of pig iron can be produced by the consumption of only 17 cwt. of coke which is the proportion adopted in the following calculation :—

$$17 \text{ cwt. of coke at } 90\% \text{ C} = 1713.6 \text{ lbs.}$$

Though this amount of carbon, per ton of pig iron produced, is charged into the furnace, it does not all descend to the tuyeres to be acted upon by the air blast, because at the critical temperature degree the carbonic acid is liberated from the limestone flux and is capable of combining with carbon to form carbonic oxide, thus carrying out of the furnace a weight of carbon equal to its own content of carbon.

$$\text{CO}_2 = 492.8 \text{ lbs.}$$

10 cwt. of pure limestone would have in its composition 134.4 lbs. of carbon, so we can deduct that weight  $1,713.6 - 134.4 = 1,589.2$  lbs. This weight, *i.e.* 1,589.2 lbs. of carbon, therefore reaches the neighbourhood of the tuyeres and combines with the oxygen of the air to form carbonic oxide, and by working out the proportion we can ascertain the weight of oxygen and nitrogen which would be associated with this carbon.

|                                               |         |          |         |
|-----------------------------------------------|---------|----------|---------|
| $\text{C} + \text{O} = \text{CO}$ , therefore | C       | requires | O       |
| 12    16    28                                | 1,589.2 |          | 2,180.9 |

This weight of oxygen would be associated with 7,092.7 lbs. nitrogen.

We have now by weight per ton of pig iron produced :—

|          |     |              |
|----------|-----|--------------|
| Carbon   | ... | 1,589.2 lbs. |
| Oxygen   | ... | 2,118.9 lbs. |
| Nitrogen | ... | 7,092.7 lbs. |

However, the pig iron takes out of the furnace in a solid form 4% of its weight of carbon = 89.6 lbs., but as it was derived from the decomposition of the carbonic oxide gas, the nitrogen remains as a diluent of the effluent gases. We have thus :—

|                                                             |  |  |  |  |  | Carbon.     | Oxygen.         |
|-------------------------------------------------------------|--|--|--|--|--|-------------|-----------------|
| Carbon carried out by CO <sub>2</sub> ...                   |  |  |  |  |  | 134'4       |                 |
| CO, of flux ...                                             |  |  |  |  |  | 492'8       | 358'4           |
| Carbon ... 1,589'2 - 89'6 =                                 |  |  |  |  |  | 1,499'6     |                 |
|                                                             |  |  |  |  |  | C 1,768'4   |                 |
|                                                             |  |  |  |  |  | O + 2,357'9 |                 |
| Oxygen from air ...                                         |  |  |  |  |  | 2,118'9     |                 |
| Oxygen from reduction of SiO <sub>2</sub> ...               |  |  |  |  |  | 51'2        |                 |
| Oxygen from reduction of Fe <sub>2</sub> O <sub>3</sub> ... |  |  |  |  |  | 902'4       |                 |
|                                                             |  |  |  |  |  |             | 3,430'9         |
| Hydrogen from air...                                        |  |  |  |  |  | 7'4         | } 12'1          |
| Hydrogen from coke                                          |  |  |  |  |  | 4'7         |                 |
| Nitrogen ...                                                |  |  |  |  |  | 7,092'7     |                 |
| Carbonic Acid CO <sub>2</sub> (C = 804'8 O = 2,146'1)       |  |  |  |  |  | 2,950'9     | Per cent. 23'99 |
| ,, Oxide CO (C = 963'6 O = 1,284'8)                         |  |  |  |  |  | 2,248'4     | 18'27           |
|                                                             |  |  |  |  |  | 1,768'4     |                 |
|                                                             |  |  |  |  |  | 3'430'9     |                 |
| Hydrogen ...                                                |  |  |  |  |  | 12'1        | '09             |
| Nitrogen ...                                                |  |  |  |  |  | 7,092'7     | 57'65           |
|                                                             |  |  |  |  |  | 12,304'1    | 100'00          |
|                                                             |  |  |  |  |  | % Volumes.  |                 |
| CO <sub>2</sub> 23'99 ÷ 22 =                                |  |  |  |  |  | 1'090       | = 16'51         |
| CO 18'27 ÷ 14 =                                             |  |  |  |  |  | 1'305       | = 19'76         |
| H '09 ÷ 1 =                                                 |  |  |  |  |  | '090        | = 1'36          |
| N 57'65 ÷ 14 =                                              |  |  |  |  |  | 4'118       | = 62'37         |
|                                                             |  |  |  |  |  | 6'603       | 100'00          |

Thermal value per cub.

ft. at 60° F. down to

212° F. .... 66'89 B.T.U. Ratio CO : CO<sub>2</sub> = '83.

However, the lowest percentage of CO quoted in blast furnace gases is 25'5.\* So if we convert the results obtained in the example taken, we get the following results:—

By calculation. South Chicago Furnace.

|                 |        |        |                                |
|-----------------|--------|--------|--------------------------------|
| CO <sub>2</sub> | 16'51  | 12'00  |                                |
| CO              | 19'76  | 25'50  | Ratio CO : CO <sub>2</sub> '47 |
| H               | 1'36   | 1'36   |                                |
| N               | 62'37  | 61'14  |                                |
|                 | 100'00 | 100'00 |                                |

\* South Chicago Works of the North Chicago Rolling Mill Co.

Bringing the first example down to the ratio of '47, we have

|                 |               |                                  |
|-----------------|---------------|----------------------------------|
| CO <sub>2</sub> | 11'60         |                                  |
| CO              | 24'67         | Thermal value at 60° F. down to  |
| H               | 1'36          | 212° F. per cub. ft. 82'5 B.T.U. |
| N               | 62'37         |                                  |
|                 | <u>100'00</u> |                                  |

|                 | Volume<br>per cent. |   |    | Weight<br>per cent. | C               | O             | H             | N             |
|-----------------|---------------------|---|----|---------------------|-----------------|---------------|---------------|---------------|
| CO <sub>2</sub> | 11'60               | × | 22 | =                   | 255'20          | 17'30         | 4'718         | 12'582        |
| CO              | 24'67               | × | 14 | =                   | 345'38          | 23'41         | 10'032        | 13'378        |
| H               | 1'36                | × | 1  | =                   | 1'36            | '09           |               | '09           |
| N               | 62'37               | × | 14 | =                   | 873'18          | 59'20         |               | 59'20         |
|                 | <u>100'00</u>       |   |    |                     | <u>1,475'12</u> | <u>100'00</u> | <u>14'750</u> | <u>25'960</u> |

#### FURTHER NOTES ON THE QUALITY OF BLAST FURNACE GASES.

When raw coal is the sole fuel, the gases are richer in combustible than when coke is employed, the volatile gases of the coal passing into the gases are unaffected by the presence of the ore.

In coke fed furnaces the thermal value of the effluent gas is usually not lower than 100 B.T.U.s. If the addition of iron ore to the furnace was arrested for a time, and the coke was simply burned by the air blast, then the thermal value of the gas would rise to about 120 B.T.U.s.

The physical properties of the ore and coke may cause the gases to be of higher thermal value than 100 B.T.U., as stated above, for if any of the oxide is reduced by solid carbon, or the carbonic acid gas, formed by the reduction of the oxide by carbonic oxide, dissolves additional carbon from the heated carbon in its vicinity according to the following reaction,  $\text{CO}_2 + \text{C} = 2 \text{CO}$ , then the thermal value of the gas may reach to about 137 B.T.U.s.

#### BLAST FURNACE GAS CALCULATIONS.

Oct. 18th, 1898.—*Sample of Gas from Messrs. Hickman's Furnaces.*

*Furnace* No. 6.

*Date* March 28th, 1898.

*Time* 4-45 p.m. Slag Grey.

|                  |               |  |  |                 |
|------------------|---------------|--|--|-----------------|
| Analysis per     |               |  |  |                 |
| cent. by Volume. |               |  |  | Presumably by   |
| CO <sub>2</sub>  | 5'88          |  |  | Works' Chemist. |
| CO               | 37'50         |  |  |                 |
| H                | 6'12          |  |  |                 |
| N                | <u>50'50</u>  |  |  |                 |
|                  | <u>100'00</u> |  |  |                 |

The fuel in this case consists of four parts coke to one part coal.

Calculated thermal value per cub. ft. at 60° F down to 212° F = 137 British Thermal Units.

### THERMAL COMPARISON BETWEEN THE STEAM AND GAS SYSTEMS.

The thermal units required to develop one indicated horse power of energy over a period of one hour are :—

|                                                              |          |
|--------------------------------------------------------------|----------|
|                                                              | B.T.Us.  |
| For steam power as developed in ironworks boilers ...        | 43,300   |
| On the new system only 10,828 B.T.Us. are required.          |          |
| The comparison in Kilowatt units is steam for power = 72,544 |          |
| For Thwai'e-Gardner Blast Furnace System.....                | = 18,136 |

In recognising the economic and other values of any new system or invention, it is but justice to acknowledge the authors of the essential instruments that have permitted the results to be obtained. And in this new power system, as in many other modern innovations, we have to thank Germany and France,—the former gave us Dr. Otto, and the latter, M. Lenoir.

The Otto cycle of action in the internal combustion engine has only to be understood to be admired. This cycle lifted the gas engine above all possible thermodynamic rivalry by the steam engine, besides converting a noisy instrument of power production into one of a silent character. Fig.4 gives the rising line of progress of gas engine efficiency.

### THE COMPARATIVE THERMODYNAMIC PERFECTION OF THE GAS ENGINE.

The gas engine may therefore be said to possess a very high thermodynamic qualification, and is, therefore, ideally fitted to work in harness with those other perfect instruments—the Alternating Tri- and Multiphase Electric Generators.

The two instruments of power production constitute the New Power System as a possibly economically unrivalled source of power that in certain respects has advantages over water power.

### THE REMARKABLE CALORIFIC UNIFORMITY OF THE GASES FROM ANY ONE FURNACE.

The new system has this remarkable essential, that owing to its immensity of gaseous production, the thermal potential of gas is so remarkably constant as to permit cylinders of great dimensions to be used with perfect safety. The variable thermal character of other gaseous fuels is fatal to the employment of large units of power; this difficulty is removed by the new power system, and quadruple or bi-cylindrical engines of 1,000 I.H.P. can be provided.

Happily for the Eastern, the Southern States of America, for England, and for manufacturing centres on the Continent of Europe, blast furnaces have constituted the nuclei around which industrial enterprise has gathered its elements of production, and, therefore, the possibility of disposing the dynamic power generated at a profitable price is promising and excellent.

**THE ECONOMIC IMPORTANCE OF THE NEW SYSTEM TO SMALL BLAST FURNACE OWNERS.**

Instead of these industrially centred blast furnaces having to be blown out by the rival and modern colossal furnaces, which are magnificent examples of American enterprise, the smaller furnaces well distributed in centres of power demand will be able to continue their useful existence providing in addition to the democratic metal—pig iron—all the power and light requirements of a manufacturing centre and under the most satisfactory conditions; so that although the great lights from the mouths of our blast furnaces have been extinguished by the hand of science, the light will still be given in a better way to all the homes and workshops—within a radius of 25 miles from the ironworks.

Installations are being designed in which the metallic product of the furnaces will be cast direct into mercantile castings, and the entire thermal value of the gases, except that of a sensible character, and which will be utilised for heating the blast, will be employed for generating heat to be thermally and afterwards electrically transformed.

Such a plant will be capable of distributing electric power to the terminals of customers' dynamos, at a cost below competition with any other fuel power.

Where the ironworks are associated with steel works the electric energy can be used for electric heating and power purposes. That it is possible to utilize heat energy electrically transformed more economically than by direct application, owing to the possibility of high concentration that the former possesses, has long ago been demonstrated by Mr. B. H. Thwaite.

**THE IMMENSE FIELD FOR ELECTRIC ENERGY CHEAPLY PRODUCED.**

In the development of use of the still youthful electrical power there is the possibility of an immense and altogether incalculable extension, and every step that reduces the first cost of its production amplifies the sphere of economic application. The Thwaite-Gardner Blast Furnace power system is either in use or is being applied for lighting power transmission, calcic carbide production, electro fusion, and other purposes.

The steady driving qualification of the new system has enabled the gas engine to be employed for alternator driving in parallel—a crucial test for gas engine steadiness.

To compensate for the arrest of the gas supply in stopping or blowing out and for blowing in a furnace, a pair of auxiliary gas generators (Fig. 5) are provided. These generators are coupled up to the blast furnace gas treatment plant. They can be set to work in an hour and a half, and their stand-by costs are quite negligible, because unlike a steam boiler, which is often utterly ruined by simple disuse, a gas generator never having to sustain any serious pressures, its mere

exposure to weather, if painted at reasonable and regular intervals, will not destroy its efficiency, at any rate within a period of the next fifty years.

The provision of auxiliary gas generators obviates the necessity of employing large gas-holders.

#### CONSIDERATIONS ASSOCIATED WITH THE PRACTICAL APPLICATION OF THE NEW POWER SYSTEM.

In a set of three or four furnaces, it is never intended, except for special applications, to apply the system to the full complement of the furnaces, but to leave one furnace in reserve, so that if there is found to be any necessity to blow out any one of them, the available supply of gas will not be reduced. It will, however, be obvious, that the stern mercantile factors that control the active operations of a furnace, will be intercepted by the possibility of working the furnaces for power production purposes only, and the necessity of blowing out a furnace will be reduced, if not entirely removed, and this especially applies to furnaces in which ammonia and tar recovery processes are in operation, because the cessation of working of a blast furnace would mean the stoppage of this source of profit. Another advantage that has not been referred to, and which would follow the application of the new system when fully applied, is the fact that in order to effect the recovery of ammonia, it is necessary to remove the sensible heat of the blast furnace gases as they flow from the furnace. This is a thermal loss that is inevitable if ammonia is to be recovered, and the thermal sacrifice is not inconsiderable. It represents 4.4% of the original thermal potential of the fuel. Now this loss in the complete application of the Thwaite-Gardner System is avoided. But even if the system is not completely applied, the fact that the sensible heat of the gases has to be removed to permit the gas to be used in the gas engine as well as for the ammonia process divides the risk and reduces its importance in a still greater proportion.

Another loss associated with the ordinary blast furnace practice may be referred to, that is, the one that accompanies the lowering and raising of the bell. This loss will be prevented by one of the series of patents that control the use of the new system of using blast furnace gases.

#### THE FINANCIAL POTENTIAL OF BLAST FURNACE GASES.

When blast furnace gases represented the low potential of financial value, that they did prior to the introduction of the new system, it was roughly immaterial whether the gas was badly burnt in imperfectly designed or worked hot blast stoves, or whether it was practically thrown away by its use in a steam boiler, but now, carrying as it does and without involving any appreciable addition to labour and other costs, the possibility of securing another source of profit, *every cubic foot of the*

*gas should be saved. It may almost be said that a cubic foot saved is an engine driven.* It is actually true to say that one cubic foot burnt will raise 22,372 lbs. one foot high, and the gas given in proportion to thermal value a higher thermodynamic efficiency than even expensive retort gas. The expression, thrown away, in describing the employment of this gas in a steam boiler is none *too forcible* when it is understood that at least four times the volume of gas is required if burnt in a steam boiler that would be necessary to develop the same power by combustion in a gas engine cylinder. It will be readily acknowledged that such a method involves a disgraceful thermal waste and is quite out of harmony with the laws of the conservation of energy.

There is in a steam boiler plant an environment of danger as well as a serious financial risk. By the action of the new law for compensating injured workmen, one steam boiler explosion of normal magnitude in its proportion of disaster to life and limb, will mean the provision of a compensatory figure that will spell complete ruin to the ironmaster. Blast furnace steam boilers are ordinarily exposed to the worst possible conditions, and between the influence of the weather and varying temperatures without and corrosion and incrustation within, these elements of danger and thermal waste (blast furnace steam boilers) have only a short life. It is to be hoped that the new power system will provide a means of bringing a speedy end to the old and dangerous order. Even applying the factor of 4 to 1 it would be seen to mean that the displacement of the steam boilers represents three-quarters of the power formerly developed which would be set free and available for other purposes. And this saving expressed in financial terms on the full year's run will be found to represent a very startling figure.

#### SUMMARY OF SALIENT AND SPLENDID ADVANTAGES.

The accuracy of the following information of the Thwaite-Gardner B.F. Power System can be guaranteed :—

a. That multiple cylinder engines working on the Otto Cycle in units of from 300 to 600 I.H.P., and in aggregation of such units as to develop any power required can be provided.

b. That these gas engines will develop one actual or brake horse power of output, with an expenditure of 1.15 to 1.50 lb. of fuel fed into the blast furnace in regular every day work.

c. That the average pressure on the piston with gas of 100 B.T.U.s. of value per cubic foot shall never be less than 70 lbs. See figure.

d. That their steadiness of running shall be such that a copper coin shall be balanced edgways on the frame of the engine and remain standing during the running of the engine at maximum load. See figure.

*e.* That the average consumption of thermal energy per kilowatt hour of electrical power developed shall not exceed 18,137 thermal units.

*f.* That there shall be no greater, if as much, supervision required, than in any high-class steam engine of the Corliss type.

*g.* That there will be no necessity to provide a higher factor of depreciation or maintenance than is required for such an engine as that of the Corliss steam engine.

*h.* That the gas treatment plant will be durable for quite 100 years against the steam boiler life (and one always of danger) of only 10 to 15 years.

#### THE CHARACTER OF THE APPLICATION WILL VARY FOR DIFFERENT FURNACES.

An extensive and personal examination of many blast furnace plants reveals the fact that the application of the blast furnace power system will vary considerably. There is scarcely one works that can be considered a replica of another, and each application will involve separate and distinctive methods of treatment, but the new system is applicable to all existing blast furnaces in a more or less great degree applicable to all blast furnaces.

As a central source of fuel power for electrical transmission, on the plan originally outlined by Mr. B. H. Thwaite, vide "Electrical Transmission of Power from the Coal Fields," before the Manchester Association of Engineers, in 1892, the blast furnace offers exceptional advantages. For the distribution of electric power, the well-distributed position of the furnaces in the Staffordshire district offers no difficulties whatsoever.

The pig iron industry is the father of many smaller industries, and it is particularly appropriate that this great monument of practical science, the blast furnace, should be also the fountain head for the flow of power to all the industries in the neighbourhood.

The iron masters should see to it that no scheme of electrical power distribution should be permitted to mature, unless it involves the possible employment of at least part of the power they may have available for sale, otherwise the possible outlet at a reasonably profitable price, for the power that may be available from each furnace would be cut off.

#### THWAITE-GARDNER BLAST FURNACE POWER PLANT AT BORBECK.

This plant, which is in operation at the Phoenix Hutte, Borbeck, Rheinland, has for its object, the supply of electric energy for the manufacture of calcic carbide.

The gas for the gas engine is taken from the main tubing leading from the blast furnaces, and has the following average composition :—

## Blast Furnace Gas, Phoenix Hutte.

Average percentage composition by Volume.

|                |                 |                    |
|----------------|-----------------|--------------------|
| Carbonic Acid  | CO <sub>2</sub> | 7·85               |
| Oxygen         | O               | ·15                |
| Carbonic Oxide | CO              | 30·70              |
| Hydrogen       | H               | 3·28               |
| Marsh Gas      | CH <sub>4</sub> | ·50                |
| Nitrogen       | N               | 57·52              |
|                |                 | <hr/> 100·00 <hr/> |

Thermal value per cubic foot, at 60° F. down to 212° F., 111·72 British Thermal Units.

This gas in the gas engine cylinder develops a mean pressure, as shown by the indicator, of 60 to 70lbs. per square inch.

The engine is 150 indicated horse power, and is situated in a building alongside the calcic carbide fallory, and drives an alternating dynamo direct from its fly-wheel. The consumption of gas per indicated horse power hour will be less than 100 cubic feet, which is equivalent, say, to one indicated horse power developed for every 1·3lbs. of coke charged into the blast furnace, and this result, taken in conjunction with the fact that the fuel also provides the necessary heat and reducing environment for the production of pig iron, shows as a practical economical combination, a very near approach to perfection, and must deeply impress blast furnace managers of the value of every cubic foot of gas produced, as well as the loss sustained for every cubic foot allowed to pass into the atmosphere without having been properly turned to account.

## APPENDIX I.

## COMPARATIVE VOLUME OF AIR REQUIRED—TOWN &amp; B. F. GA

|                               |     |     | Coal Gas.<br>Volume. | Air required.<br>O. | N.            |             |
|-------------------------------|-----|-----|----------------------|---------------------|---------------|-------------|
| CO <sub>2</sub>               | ... | ... | 1'41                 | —                   | —             |             |
| C <sub>2</sub> H <sub>4</sub> | ... | ... | 3'84                 | 17'28               | 69'12         |             |
| C <sub>3</sub> H <sub>6</sub> | ... | ... |                      |                     |               |             |
| C <sub>4</sub> H <sub>8</sub> | ... | ... |                      |                     |               |             |
| C <sub>6</sub> H <sub>6</sub> | ... | ... | 1'04                 | 7'80                | 31'20         |             |
| O                             | ... | ... | '30                  | —                   | —             |             |
| CO                            | ... | ... | 6'15                 | 3'07                | 12'28         |             |
| H                             | ... | ... | 47'73                | 23'86               | 95'44         |             |
| CH <sub>4</sub>               | ... | ... | 35'63                | 71'26               | 285'04        |             |
| N                             | ... | ... | 3'90                 | —                   | —             |             |
|                               |     |     | <u>100'00</u>        | <u>123'27</u>       | <u>493'08</u> | Total, 716' |
|                               |     |     |                      | <u>616'35</u>       |               |             |

Theoretically, 1 volume of coal gas requires 6 volumes of air.

|                 |     |     | Blast Furnace Gas.<br>Volume. | Air required.<br>O. | N.          |             |
|-----------------|-----|-----|-------------------------------|---------------------|-------------|-------------|
| CO <sub>2</sub> | ... | ... | 10'4                          | —                   | —           |             |
| CO              | ... | ... | 25'6                          | 12'8                | 51'2        |             |
| H               | ... | ... | 2'4                           | 1'2                 | 4'8         |             |
| CH <sub>4</sub> | ... | ... | 1'2                           | 2'4                 | 9'6         |             |
| N               | ... | ... | 60'4                          | —                   | —           |             |
|                 |     |     | <u>100'0</u>                  | <u>16'4</u>         | <u>65'6</u> | Total, 182' |
|                 |     |     |                               | <u>82'0</u>         |             |             |

Theoretically, 1 volume of B. F. gas requires '8 volumes of air.

## APPENDIX II.

## BLAST FURNACE.—EXAMPLE I.

*Calculated Composition of the Waste Gases.*

Per ton of pig iron. Coke per ton of pig 22·69 cwts.

|                                                                       | Carbon<br>cwts. | Oxygen<br>cwts. | Carbon<br>cwts. | Oxygen<br>cwts. |
|-----------------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Carbon in coke, 20·24 cwts. burnt to CO                               | ...             | ...             | 20·240          | 26·990          |
| From the above must be taken :—                                       |                 |                 |                 |                 |
| Carbon dissolved in the pig iron ...                                  | ·750            | 1·000           |                 |                 |
| Carbon in CO <sub>2</sub> in limestone and C<br>taken up by it ... .. | 1·197           | 1·600           |                 |                 |
| Silica reduced by carbon ... ..                                       | ·495            | ·660            |                 |                 |
| Lime to sulphide of calcium by C                                      | ·030            | ·040            |                 |                 |
|                                                                       | <u>2·472</u>    | <u>3·300</u>    |                 |                 |
|                                                                       |                 |                 | 2·472           | 3·300           |
|                                                                       |                 |                 | <u>17·768</u>   | <u>23·690</u>   |

The Nitrogen for 23·69O = 23·25 : 23·69 :: 76·75 : 78·20 cwts.

To the above must be added :—

|                                                                  | Carbon<br>cwts. | Oxygen<br>cwts. |               |               |
|------------------------------------------------------------------|-----------------|-----------------|---------------|---------------|
| C and O in CO <sub>2</sub> in limestone and<br>C taken up ... .. | 2·394           | 3·193           |               |               |
| O from oxides of iron & manganese                                |                 | 8·150           |               |               |
| O from Si O <sub>2</sub> reduced ... ..                          | ·495            | ·660            |               |               |
| O from Ca O to Ca S ... ..                                       | ·030            | ·040            |               |               |
|                                                                  | <u>2·919</u>    | <u>12·043</u>   |               |               |
|                                                                  |                 |                 | 2·919         | 12·043        |
|                                                                  |                 |                 | <u>20·687</u> | <u>35·733</u> |

Total weight of gases,  
cwts.

|          |                |                               |               |        |       |
|----------|----------------|-------------------------------|---------------|--------|-------|
| Carbon   | 20·687         | Carbonic Acid CO <sub>2</sub> | 22·41         | Carbon | 6·11  |
| Oxygen   | 35·733         | Carbonic Oxide CO             | 34·01         | Carbon | 14·58 |
| Nitrogen | 78·200         | Nitrogen N                    | 78·20         |        |       |
|          | <u>134·620</u> |                               | <u>134·62</u> |        |       |

*Percentage composition.*

| By weight.                    |              | By volume. |              |
|-------------------------------|--------------|------------|--------------|
| Carbonic acid CO <sub>2</sub> | 16.64        |            | 11.27        |
| Carbonic oxide CO             | 25.26        |            | 26.88        |
| Nitrogen N                    | 58.09        |            | 61.84        |
|                               | <u>99.99</u> |            | <u>99.99</u> |

This calculation assumes that the oxide of iron is reduced by carbonic oxide, and that the resulting carbonic acid remains permanent.

**BLAST FURNACE.—EXAMPLE II.***Calculated Composition of the Waste Gases.*

Per ton of pig iron. Coke per ton of pig 17.00 cwts.

|                                                                | Carbon<br>cwts. | Oxygen<br>cwts. | Carbon<br>cwts. | Oxygen<br>cwts. |
|----------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Carbon in coke, 15.3 cwts. burnt to CO                         | ...             | ...             | 15.300          | 20.400          |
| From the above must be taken :—                                |                 |                 |                 |                 |
| Carbon dissolved by the pig iron                               | 0.800           | 1.058           |                 |                 |
| Carbon in CO <sub>2</sub> in limestone and C<br>taken up by it | ...             | ...             | ...             | ...             |
| Silica reduced by carbon                                       | ...             | 0.495           | ...             | 0.660           |
| Lime to sulphide of calcium by C                               | ...             | 0.030           | ...             | 0.040           |
|                                                                | <u>2.522</u>    | <u>3.358</u>    |                 |                 |
|                                                                |                 |                 | <u>2.522</u>    | <u>3.358</u>    |
|                                                                |                 |                 | 12.778          | 17.042          |

The Nitrogen for 17.042 O = 23.25 : 17.042 :: 76.95 : 56.26. cwts.

To the above must be added :—

|                                                           | Carbon.      | Oxygen.       |              |               |
|-----------------------------------------------------------|--------------|---------------|--------------|---------------|
| C and O in CO <sub>2</sub> in limestone and<br>C taken up | ...          | ...           | 2.394        | 3.193         |
| O from oxides of iron and manganese                       | ...          | ...           | 8.150        |               |
| O from Si O <sub>2</sub> reduced                          | ...          | ...           | 0.495        | 0.660         |
| O from Ca O to Ca S                                       | ...          | ...           | 0.030        | 0.040         |
|                                                           | <u>2.919</u> | <u>12.043</u> |              |               |
|                                                           |              |               | <u>2.919</u> | <u>12.043</u> |
|                                                           |              |               | 15.697       | 29.085        |

Total weight of gases,  
cwts.

|          |                |                               |               |        |      |
|----------|----------------|-------------------------------|---------------|--------|------|
| Carbon   | 15.697         | Carbonic Acid CO <sub>2</sub> | 22.44         | Carbon | 6.12 |
| Oxygen   | 29.085         | Carbonic Oxide CO             | 22.33         | Carbon | 9.57 |
| Nitrogen | 56.260         | Nitrogen N                    | 56.26         |        |      |
|          | <u>101.042</u> |                               | <u>101.03</u> |        |      |

*Percentage composition.*

| By weight.                    |               | By volume. |               |
|-------------------------------|---------------|------------|---------------|
| Carbonic acid CO <sub>2</sub> | 22.21         |            | 15.37         |
| Carbonic oxide CO             | 22.10         |            | 24.05         |
| Nitrogen N                    | 55.69         |            | 60.58         |
|                               | <u>100.00</u> |            | <u>100.00</u> |

This calculation assumes that the oxide of iron is reduced by carbonic oxide, and that the resulting carbonic acid remains permanent.

## BLAST FURNACE.—EXAMPLE III.

*Calculated Composition of the Waste Gases.*

Per ton of pig iron. Coke per ton of pig, 22.69 cwts.

|                                                                    | Carbon<br>cwts. | Oxygen<br>cwts. | Carbon<br>cwts. | Oxygen<br>cwts. |
|--------------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Carbon in coke, 20.24 cwts., burnt to CO.                          | ...             | ...             | 20.240          | 26.990          |
| From the above must be taken :—                                    |                 |                 |                 |                 |
| Carbon dissolved in the pig iron...                                | .750            | 1.000           |                 |                 |
| Carbon in CO <sub>2</sub> in limestone and C<br>taken up by it ... | 1.197           | 1.600           |                 |                 |
| Silica reduced by carbon ...                                       | .495            | .660            |                 |                 |
| Lime to sulphide of calcium by C                                   | .030            | .040            |                 |                 |
| Carbon dissolved by carbonic acid                                  | 3.000           | 4.000           |                 |                 |
|                                                                    | <u>5.472</u>    | <u>7.300</u>    | <u>5.472</u>    | <u>7.300</u>    |
|                                                                    |                 |                 | 14.768          | 19.690          |

The Nitrogen for 19.69 O = 23.25 : 19.69 :: 76.75 : 64.99 cwts.

|                                                               | Carbon<br>cwts. | Oxygen<br>cwts. |              |               |
|---------------------------------------------------------------|-----------------|-----------------|--------------|---------------|
| To the above must be added :—                                 |                 |                 |              |               |
| C and O in CO <sub>2</sub> in limestone and<br>C taken up ... | 2.394           | 3.193           |              |               |
| O from oxide of iron and manganese                            | —               | 8.150           |              |               |
| O from SiO <sub>2</sub> reduced ...                           | .495            | .660            |              |               |
| O from CaO to CaS ...                                         | .030            | .040            |              |               |
| C dissolved by CO <sub>2</sub> ...                            | 3.000           | —               |              |               |
|                                                               | <u>5.919</u>    | <u>12.043</u>   | <u>5.919</u> | <u>12.043</u> |
|                                                               |                 |                 | 20.687       | 31.733        |

Total weight of Gases,  
cwts.

|          |                |                               |               |        |       |
|----------|----------------|-------------------------------|---------------|--------|-------|
| Carbon   | 20.687         | Carbonic Acid CO <sub>2</sub> | 11.41         | Carbon | 3.11  |
| Oxygen   | 31.733         | Carbonic Oxide CO             | 41.02         | Carbon | 17.58 |
| Nitrogen | 64.990         | Nitrogen N                    | ...           |        |       |
|          | <u>117.410</u> |                               | <u>117.42</u> |        |       |

*Percentage Composition.*

|                             | By weight.    | By volume.    |
|-----------------------------|---------------|---------------|
| Carbonic Acid $\text{CO}_2$ | 9.72          | 6.42          |
| Carbonic Oxide CO           | 34.93         | 36.22         |
| Nitrogen N                  | 55.35         | 57.37         |
|                             | <u>100.00</u> | <u>100.01</u> |

This calculation assumes that the oxide of iron is reduced by carbonic oxide, and that the carbonic acid formed dissolves 3 cwts. of carbon.

**BLAST FURNACE.—EXAMPLE IV.***Calculated Composition of the Waste Gases.*

Per ton of pig iron. Coke per ton of pig 22.69 cwts.

|                                                                     | Carbon<br>cwts. | Oxygen<br>cwts. | Carbon<br>cwts. | Oxygen<br>cwts. |
|---------------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Carbon in coke, 20.24 cwts. burnt to CO                             | ...             | ...             | 20.240          | 26.990          |
| From the above must be taken :—                                     |                 |                 |                 |                 |
| Carbon dissolved in the pig iron                                    | .750            | 1.000           |                 |                 |
| Carbon in $\text{CO}_2$ in limestone and C<br>taken up by it        | 1.197           | 1.600           |                 |                 |
| Silica reduced by carbon                                            | .495            | .660            |                 |                 |
| Lime to sulphide of calcium by C                                    | .030            | .040            |                 |                 |
| $\text{Fe}_2\text{O}_3$ reduced by solid carbon<br>(3 cwts. of Fe.) | .964            | 1.285           |                 |                 |
|                                                                     | <u>3.436</u>    | <u>4.585</u>    | <u>3.436</u>    | <u>4.585</u>    |
|                                                                     |                 |                 | 16.804          | 22.405          |

The Nitrogen for 22.40 cwts. O = 23.25 : 22.40 :: 76.75 : 73.65 cwts.

To the above must be added :—

|                                                         | Carbon<br>cwts. | Oxygen<br>cwts. |              |               |
|---------------------------------------------------------|-----------------|-----------------|--------------|---------------|
| C and O in $\text{CO}_2$ in limestone and<br>C taken up | 2.394           | 3.193           |              |               |
| O from oxides of iron & manganese                       |                 | 8.150           |              |               |
| O from $\text{SiO}_2$ reduced                           | .495            | .660            |              |               |
| O from CaO to CaS                                       | .030            | .040            |              |               |
| C to reduce Fe from $\text{Fe}_2\text{O}_3$             | .964            |                 |              |               |
|                                                         | <u>3.883</u>    | <u>12.043</u>   | <u>3.883</u> | <u>12.043</u> |
|                                                         |                 |                 | 20.687       | 34.448        |

**Total weight of gases,  
cwts.**

|          |               |                               |               |        |        |
|----------|---------------|-------------------------------|---------------|--------|--------|
| Carbon   | 20·69         | Carbonic acid CO <sub>2</sub> | 18·88         | Carbon | 5·15.  |
| Oxygen   | 34·44         | Carbonic oxide CO             | 36·26         | Carbon | 15·54. |
| Nitrogen | 73·76         | Nitrogen                      | ... 73·76     |        |        |
|          | <u>128·89</u> |                               | <u>128·90</u> |        |        |

*Percentage Composition.*

| By weight.                    |               | By volume.    |
|-------------------------------|---------------|---------------|
| Carbonic acid CO <sub>2</sub> | 14·64         | 9·83          |
| Carbonic oxide CO             | 28·13         | 29·71         |
| Nitrogen N                    | 57·23         | 60·46         |
|                               | <u>100·00</u> | <u>100·00</u> |

This calculation assumes that the oxide of iron is reduced by carbonic oxide and solid carbon, the resulting carbonic acid remaining permanent.

**BLAST FURNACE.—EXAMPLE V.***Calculated Composition of the Waste Gases.*

Per ton of pig iron. Coke per ton of pig iron, 22·69 cwts.

|                                                                | Carbon<br>cwts. | Oxygen<br>cwts. | Carbon<br>cwts. | Oxygen<br>cwts. |
|----------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Carbon in coke, 20·24 cwts. burnt to CO                        | ...             | ...             | 20·240          | 26·990          |
| From the above must be taken :—                                |                 |                 |                 |                 |
| Carbon dissolved in pig iron                                   | ... 750         | 1·000           |                 |                 |
| Carbon in CO <sub>2</sub> in limestone and C<br>taken up by it | ... 1·197       | 1·600           |                 |                 |
| Silica reduced by carbon                                       | ... 495         | ·660            |                 |                 |
| Lime to sulphide of calcium by C                               | ... 030         | ·040            |                 |                 |
| Fe <sub>2</sub> O <sub>3</sub> reduced by solid carbon         | ... 5·972       | 7·963           |                 |                 |
|                                                                | <u>8·444</u>    | <u>11·263</u>   | <u>8·444</u>    | <u>11·263</u>   |
|                                                                |                 |                 | 11·796          | 15·727          |

The Nitrogen for 15·73 O = 23·25 : 15·73 :: 76·75 : 51·92 cwts.

To the above must be added :—

|                                                        | Carbon<br>cwts.                   | Oxygen<br>cwts. |        |        |
|--------------------------------------------------------|-----------------------------------|-----------------|--------|--------|
| C and O in CO <sub>2</sub> in limestone and            |                                   |                 |        |        |
| C taken up ... ..                                      | 2'394                             | 3'193           |        |        |
| O from oxides of iron & manganese                      |                                   | 8'150           |        |        |
| O from Si O <sub>2</sub> reduced ... ..                | '495                              | '660            |        |        |
| O from Ca O to Ca S ... ..                             | '030                              | '040            |        |        |
| C to reduce Fe from Fe <sub>2</sub> O <sub>3</sub> ... | 5'972                             |                 |        |        |
|                                                        | 8'891                             | 12'043          | 8'891  | 12'043 |
|                                                        |                                   |                 | 20'687 | 27'770 |
| Total weight of gases,<br>cwts.                        |                                   |                 |        |        |
| Carbon 20'687                                          | Carbonic acid CO <sub>2</sub> '51 | Carbon '140     |        |        |
| Oxygen 27'770                                          | Carbonic oxide CO 47'94           | Carbon 20'547   |        |        |
| Nitrogen 51'920                                        | Nitrogen N 51'92                  |                 |        |        |
|                                                        | 100'377                           | 100'37          |        |        |

*Percentage Composition.*

|                               | By weight. | By volume. |
|-------------------------------|------------|------------|
| Carbonic acid CO <sub>2</sub> | '51        | '8         |
| Carbonic oxide CO             | 47'76      | 47'5       |
| Nitrogen N                    | 51'73      | 51'7       |
|                               | 100'00     | 100'0      |

This calculation assumes that the oxide of iron is reduced by solid carbon.

## APPENDIX III.

AN ESTIMATE OF THE PROPORTION OF THE GASES EVOLVED  
FROM A BLAST FURNACE REQUIRED FOR HEATING THE  
BLAST IN FIREBRICK STOVES.

*Hypothesis:—*

Make of furnace, 185 tons per day.

Coke used per ton of pig iron, 1,750lbs.

Temperature of blast, 1,400°F.

Rise of temperature of blast in stoves, 1400-60 = 1,340°F.

Specific heat of air .2374 (assumed to be equal at all temperatures).

Temperature of products of combustion at stoves, 670°F.

Analysis of the effluent gases, per cent. :—

| Volume.        |                 |      | Weight. required. |        | O.      | N.    | Products. |        |
|----------------|-----------------|------|-------------------|--------|---------|-------|-----------|--------|
|                |                 |      |                   |        | with O. |       |           |        |
| Carbonic acid  | CO <sub>2</sub> | 8.9  | 13.50             |        |         |       |           | 56.84  |
| Carbonic oxide | CO              | 29.6 | 27.58             | 15.76  |         |       |           |        |
| Hydrogen.....  | H               | 1.5  | .10               | .80    |         |       | Water     | .90    |
| Nitrogen ..... | N               | 61.0 | 58.82             |        |         | 55.44 |           | 114.26 |
|                |                 |      | 100.0             | 100.00 |         |       |           | 172.00 |

*Demonstration:—*

$$\begin{array}{rcl}
 56.84 \times .216 \times 674 & 7,975 \\
 .90 \times .475 \times 674 & 288 \\
 114.26 \times .244 \times 674 & 18,791
 \end{array}
 \left. \vphantom{\begin{array}{rcl} 56.84 \\ .90 \\ 114.26 \end{array}} \right\} 27,054 \text{ B.T.U. carried off per}$$

100lbs. of gas consumed.

| Gases<br>by weight. |       | Heat Units per<br>100lbs of gases. |  | Gases<br>by volume. |      | Weight of<br>one cubic foot. |     |
|---------------------|-------|------------------------------------|--|---------------------|------|------------------------------|-----|
| CO <sub>2</sub>     | 13.50 |                                    |  | CO <sub>2</sub>     | 8.9  | .01039                       |     |
| CO                  | 27.58 | 119,311                            |  | CO                  | 28.6 | .02113                       |     |
| H                   | .10   | 5,334                              |  | H                   | 1.5  | .00008                       |     |
| N                   | 58.82 |                                    |  | N                   | 61.0 | .04525                       |     |
| 100.00              |       | 124,645                            |  | 100.0               |      | .07685                       | lb. |

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| Per cubic foot.                        |     |     |     |     |     |              |
|----------------------------------------|-----|-----|-----|-----|-----|--------------|
| Total Heat Units                       | ... | ... | ... | ... | ... | 95.78        |
| Heat Units carried off by products     | ... | ... | ... | ... | ... | <u>20.79</u> |
| „ „ available for heating the blast... | ... | ... | ... | ... | ... | <u>74.99</u> |

|                             |     |     |     |     |             |
|-----------------------------|-----|-----|-----|-----|-------------|
| Make of furnace per hour    | ... | ... | ... | ... | 7.708 tons. |
| Coke used per hour          | ... | ... | ... | ... | 13,489 lbs. |
| Air blast required per hour | ... | ... | ... | ... | 59,891 lbs. |

Sp. ht.

$$59,891 \times .2374 \times 1,340^{\circ} = 19,644,248 \text{ B.T.U.}$$

$$\text{Add 10\% for radiation, etc.} \quad \dots \quad 1,964,424$$

$$\text{Heat Units required} \quad \dots \quad 21,608,672$$

1 cubic foot of gas equals 74.99 B.T.U. in heating the air.

Cubic feet of gas to heat the blast, 288,154.

The total volume of the gases evolved per hour equals

$$13,489 \times 6.34 = 85,520 \text{ lbs.}$$

$$\frac{85,520}{.0768}$$

$$= 1,113,541 \text{ cubic feet.}$$

$$.0768$$

Therefore, in this case, nearly one-fourth of the evolved gases are required for heating the blast, leaving thus three-quarters of the heating power of the gases for power generation (including the blowing engines.)

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\* Factor = Weight of coke  $\times$  6.34 equals weight of gases.

## APPENDIX IV.

From the French Metallurgical Journal, "L'Ancre de Saint-Dizier," dated 6th December, 1898.

Letter addressed to the Editor by a Correspondent, dated 4th December:—

"Dear Sir,—Having seen in your last issue an announcement that Messrs. Thwaite and Gardner have started a large gas engine at Phoenix Hutte, at Berge-Borbeck, near Essen, driven by purified blast furnace gases, I visited that place, where I had the pleasure of meeting Mr. Thwaite. I may say at once that I am very pleased with what I saw. Having already seen the small installation of the system at Wishaw, I was very curious to see how a large motor would work, and I have no hesitation in saying that the results will be equally satisfactory as at Wishaw, which has worked with every satisfaction and regularity for about three years, lighting up the works by electricity.

"The Phoenix plant includes, besides the special gas purifying apparatus, a gas engine with two horizontal cylinders. This was started in my presence by a single mechanic, in half a minute, with the aid of a small barring engine of about 3 h.p., which turns easily by the hand.

"So soon as the little engine has acquired its normal speed it transmits by means of a belt its motion to the large engine; after a few revolutions, this has sufficient speed to effect the compression of the explosive mixture, that at the proper moment the mechanic admits into one of the two cylinders. The ignition apparatus is then brought into play; and simultaneously the little engine ceases to be charged with explosive mixture; the second cylinder undergoes the same operation as the first, and the gas engine starts running.

"At five different intervals, I have noted by my watch, during periods of one minute the speed of the engine, by counting the strokes of one of the pistons, and have always found exactly 135 revolutions per minute (the engine running free). The motor is one of 180 i.h.p., and consumption of gas  $2\text{m}^3\text{75}$  per hour. During the whole time, a silver coin remained balanced on one of the cylinders, showing that there is no appreciable vibration.

"To conclude, I note amongst the apparatus, an electrical automatic bell, which draws attention immediately to all variation of pressure in the blast furnace gases, and to the chargings, meltings, &c., as they go on in the cycle of operations.

"I shall shortly send you a more detailed description."

The installation at Phoenix Hutte, Berge-Borbeck, has been seen in operation by eminent Continental scientific men, and they all express their delight with the working of the plant. The dynamo is of alternating type, made by Messrs. Lahmeyer, of Frankfort.

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## APPENDIX V.

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### AN EXAMPLE OF ECONOMY.

Taking for instance a boiler 30ft. oin. long and 7ft. 6in. diameter, capable of evaporating 3,600 lbs. of water per hour with blast furnace gas, which will drive 120 i.h.p. with an engine consuming 30lbs. of water per horse power per hour, and a gas consumption of 600 cubic feet of gas per i.h.p. per hour.

If this boiler is taken out and the gas applied for internal combustion in the cylinders of a gas engine, then there will be, with the same quantity of gas, power equal to between 600 to 700 indicated horse power.

At the conclusion of the paper, several lantern views were shown, including the following:—A gas engine driving a mill. Further machinery driven by a gas engine, arranged with a pair of cylinders side by side, with one impulse every revolution. A collection of electric apparatus by Lahmeyer. A ten-ton travelling crane worked by an electric motor. Electric mining locomotive. An illustration of the Thwaite gas-producing plant, suitable for blast furnace work, to be employed for developing power when furnaces are standing. This plant would do as a stand-by in case of a break down of plant for utilising waste blast furnace gas. It could be started in  $1\frac{1}{2}$  hours, and is capable of producing 300 indicated horse power. There is no steam at all used, hot-air blast being employed instead. The gas made in this producer works a gas engine, the fuel used amounting to only  $1\frac{1}{2}$  lbs. of coke per indicated horse power per hour. Views of the Borbeck engine. An engine of a similar type, driven by the generator previously shown. An exterior view of plant for utilising blast furnace gas. A view of the Frodingham Furnaces, where the Thwaite-Gardner system of utilising blast furnace gas was first put down in England. This plant is intended for coke-fed furnaces. Another view of a portion of a similar plant, showing blower, which passes the blast furnace gases on to a gas engine driving a dynamo.

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## THE DISCUSSION.

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THE PRESIDENT: We have had not only an interesting, but also a very instructive paper, and one that calls for a considerable amount of thought. It involves so many possibilities that one can hardly grasp what the future of this gigantic discovery (if I may so call it) will really produce. We seem to be on the verge of an entirely new train of thought. It not only means the utilisation of blast furnace gases, but also that we should be able to utilise in a similar sense the waste gases of cupolas, and perhaps even the waste gases from our Bessemer converters.

MR. JNO. W. HALL: If there is so much power going away to waste from blast furnaces, there is no question we shall be compelled to utilise it. I regret we have not had an opportunity of getting the paper a little earlier; but speaking generally, Mr. Allen's figures as to the amount of Thermal units appear to be pretty much what we should expect. I believe gas engines do consume from  $1\frac{1}{2}$  to  $1\frac{1}{2}$  lbs. of solid fuel per indicated horse power. But I think he is a little hard upon our friend the steam engine. He reckons 30 lbs. of feed per indicated horse power; but there should be no difficulty in constructing an engine which would consume only half that quantity. So instead of saying gas engines

would consume only one-sixth as much gas fuel as steam engines, I think we should be putting it more nearly if we said  $\frac{1}{3}$  or  $\frac{1}{4}$ . But I see in another place (p. 12) he has not placed the consumption of the steam engine quite so high, for there he takes what appears to be a fair average. The question now arises, in what way must this power be utilised? We have it, and it is possible now to construct engines which will utilise this gas. I take it that is due to the high initial compression, which raises the pressure to 100lbs. per square inch, which is certainly unusual, and I see gives an initial explosive pressure of 300lbs. He also says gas engines up to 250 h.p. can be constructed, and that is important, because I think lately there has been a disposition to stop at about 75 horse power. But I don't think the distribution of this power about the district is the right way to utilise it. We had that question threshed out in Mr. Addenbrooke's paper, and if you look at the cost he gives for generating and distributing the power, it will be seen that the coal plays a very small part of the total cost. But if the waste gas can be used for the manufacture of calcium carbide on the spot, or anything of that sort, then there is undoubtedly a very great field for it. One point which strikes me as rather daring is that of the spare gas producer. I am afraid that if we are to put down gas producers as a stand-by for the blast furnace gas plant, that it will mean almost the same as putting down a second blast furnace.

Mr. A. E. TUCKER : This paper is certainly one which appeals more to blast furnace owners than to me ; but I may say, about two years ago I was called upon to make some examinations as to the composition of blast furnace gases in this district, and I found (after taking samples over a very long period, not only for many weeks together, but for many hours each time) that the composition of the gases was very similar to that quoted in the paper as coming from Messrs. Hickman's furnaces. I also found the thermal value to be very much the same as that given in the paper. But I take it that a paper of this sort is one whose value depends upon the practical efficiency of, and utilisation of, the gas after it leaves the furnace head. The first difficulty is the matter of ignition at the gas engine. I should like Mr. Allen to tell us how that is effected. At the Iron and Steel Institute, this year, Mons. Greiner pointed out the necessity of electrical ignition, and it seems to me that with the very poor igniting power of such gases in the ignition tube of a gas engine, electrical ignition is a necessity. The total available power per ton of pig made was put on that occasion in a very good way. It was pointed out that for every ton of pig made there was 20 h.p. going to waste. That figure was to some extent corroborated by Mr. James Riley, who worked it out at something like 16 or 18 horse power—a most important matter. With respect to the possible size of gas engines, Mr. Ludwig Mond said the Westinghouse Company, of Pittsburg, had already constructed gas engines of 750 horse power, and were making these high powers in considerable numbers. It would, therefore, appear that every

condition is open for the realization in South Staffordshire of the ideal which Mr. Allen has put before us this evening. The matter is out of the experimental stage, and it is to be wished that we shall soon see such enormous wastes as are now going on being duly harnessed.

Mr. H. SILVESTER : I did not intend to make any remarks on the interesting paper we have had to-night, as there are several gentlemen here who are experts in matters relating to the blast furnace, and whose opinions on the application of the waste gases to direct driving I was anxious to hear. I was struck, however, with one phrase which Mr. Allen used in the early part of the paper, "The comparative conservatism of pig iron makers," which conveys the idea that these gentlemen have been somewhat slow in adopting new ideas and methods. Well, I am inclined to think that this wise conservatism is the correct attitude to observe with regard to alterations in blast furnace practice, because if there is a metallurgical instrument to the improvement of which the old adage of "Make haste slowly" applies, it is the blast furnace, where unsuccessful modification must often mean disastrous financial loss. No smelting process affords a better illustration of sure, though perhaps sometimes slow, progress than the blast furnace. There has been a continued increase in the output, accompanied by a diminution in the amount of fuel per ton of iron made, and Mr. Allen has described to-night an installation which is in successful operation, and still further reduces the number of waste heat units that future improvers of the blast furnace will have to play with.

I should like to ask Mr. Allen whether any provision is made for the storage of the waste gases, so as to have a stand-by in the event of temporary stoppage. Then as to the washing of the gas—is there any difficulty experienced in efficiently removing the dust carried over by the gases, and which would injure the engines?

Mr. Jos. COLLEY : The author is to be congratulated upon the way in which he laid the matter before us, and especially upon the way he has shown us the possibilities of the gas engine. It will be almost a glorious time if it should come to pass that we can do away with steam boilers, for we know what a lot of trouble and anxiety they are to anyone who has anything at all to do with them.

Mr. H. PILKINGTON : I am suffering also from the disadvantage of not having read the paper before it was put into my hand to-night. I am very much struck by the fact that the blast furnace should have become one of the sources of present day power. This once despised blast furnace has progressed in my time from 20 tons a day to 600 tons, and, further than that, I believe there is no more efficient apparatus at work in this country than the blast furnace, for it utilises about 70 per cent. of the original heat units which are generated, and I don't think any steam engine, gas engine, or other heat apparatus, has done that

yet. And if, added to that, we get all these wonderful results which are promised by the author, we shall very shortly arrive at 100 per cent. efficiency. I think the blast furnace in connection with gas engines will have a very wide sphere of action, but it seems to me that the inventors have been distinctly led away by the field of operation which has been mapped out for it. The Frodingham district, in which the plant was first used with coke gas, is scarcely one in which to put the gas engine on its merits. It is not a district remarkable for economy of fuel, and there is, therefore, plenty of gas, and that of good quality. I do not think the gas engine would work on gas from one of the West Coast hematite furnaces, where fuel economy is studied, and where the fuel supply is cut down to about 19cwt. of coke per ton of pig iron produced, with 12 per cent. of moisture in the ore. It seems to me that the system would do best for furnaces which use mostly coal or an excessive amount of coke. In most of the modern plants there is no gas to spare. I can see no hope in the plant using cokes constructed on the most modern lines, for gas engines, and I know of no gas engine which has been applied to such a plant. In furnaces, however, which use coal, there is an enormous quantity of surplus gas of rich quality, and that is the field where this gas engine system would have a very useful scope. I notice that the evaporative efficiency of a 30ft. by 7ft. 6in. Lancashire boiler, costing £500, is put down at 3,600 lbs. per hour. I certainly cannot agree with that figure, because I have many times taken evaporations very much higher than that. I notice another point with regard to the use of fuel in blast furnaces, and that is the question of anthracite and coke. I take it that anthracite has practically disappeared from the field now. I was over in the United States in the Spring of this year, and had considerable difficulty in finding a blast furnace using anthracite. I should like to ask whether any practical attempt has been made to perform blast furnace operations by means of gas engines. Has there been any practical attempt to use blast furnace gas in a gas engine for driving a blowing engine? There are, of course, various kinds of power, including those for rolling mills, for tools, and for other sorts of work, and if the blast furnace gas could be utilised to drive these it would be a good thing. The firm with which I am connected is considering the question of using blast furnace gas for power for adjoining plant, and what we want to know is whether there is any hope of doing this entirely in the gas engine, and so doing away with steam boilers and engines. I think the whole of my criticisms resolve themselves into the fact that in my opinion this system will be confined to coal-fed furnaces.

Mr. WALTER JONES: I have in my mind other instances of waste power, such as brickyards, gas works, and other places; and I should like to know if the author thinks the waste heat from those sources could be made available for power?

Mr. ALLEN: I'm afraid I have scarcely been able to keep pace with the inquiries, but I will try to give what information I can. I have a

note on the utilisation of power from various sources. Very possibly waste gases from cupolas might be utilised : but cupolas generally work intermittently, whereas the blast furnace may be regarded as a continuous source of gas. The blast furnace furnishes gas night and day, and therefore it is a very good source. My calculation about 30lbs. evaporation was hastily made. I think I had it from a blast furnace manager. He said that in boilers as arranged for iron works, he thought about 30lbs. of water per indicated horse power was the most usual figure. But I only adopted that to give some sort of an idea in connection with the question of cleaning apparatus. Another question which was also put forward was the small cost of power in electrical distribution schemes. Well, to that I can only reply that, however low may be the cost of coal, the cost of blast furnace gas is still lower. If you have a furnace which gives off 150 horse power, you will get three or four times as much benefit out of it if you employ that gas in a gas engine than as though you used it to fire a steam boiler. When you have steam, the power is there, but is being badly used. As to characteristics of blast furnace gas, most blast furnace chemists say, "We always find our gas pretty much the same—very constant and very regular in quality." Mr. Hail spoke of the cost of putting down gas producers as comparable to the cost of another blast furnace. From one-quarter to one-half of the gas given off by the blast furnace is used for the stoves, but if you put down a 350 horse power gas engine for any purpose and want to provide for the stoppage of the furnace, perhaps for hours at a time, you can purchase the generator which I illustrated, and by its means you can at very small cost provide the gas necessary for the engine only. That, of course, has nothing to do with the gas that might be required for heating the blast. It would not be expensive as a substitute, and the deterioration of a producer used in this way as a stand-by would be very small because it might not often be required. As to the ignition of the blast furnace gas in the cylinder of the gas engine, we have no trouble with the installation at Borbeck, where the combustion tube is heated by the ordinary town gas. We have a system in hand of combined electricity and gas which will have the advantages of both. We are preparing plans for 1,000 indicated horse power engines for one place, and we are not likely to stop at that. Mr. Silvester has referred to the comparative conservatism of the pig iron makers, but the diagram which is given at the end of the paper shows that only 54 per cent. of the heat of the fuel is used in the furnace, so that nearly 50 per cent. is available for heating and power purposes. The storage of the gas in case of breakdowns has been considered, but has not been found practicable ; a gas-producing plant being a better alternative. The storage would require a very large gasholder, and in our case we only use a pressure governor holder. The storage apparatus would be very costly, it would have to be very large, and there is no necessity for it if the power of the engine is sufficient to warrant a stand-by generator, because the supply of power

from blast furnaces is practically constant. Mr. Colley says, do away with steam boilers. Well, we only hope we shall be able to do so. Mr. Pilkington, also referred to the question of the efficiency of the blast furnace. When I occupied the post of chemist at a large works, I always found there was a very large margin of heating power which was not made use of. And besides that, when you consider the large amount of gas which passes into the air in lowering the bell, which could be used for giving power, it is rather surprising that this waste has not been practically considered before. Every cubic foot of gas which escapes from the furnace is of considerable value when applied in the gas engine. There is another point, which is a very important one, which was referred to by Mr. Pilkington, namely, the quality of gas from furnaces using only low proportions of coke. When I first went into the matter of this paper, my original idea was to make synthetical analyses from different quantities of fuel, but I found in practice that the lowest quantity of fuel used per ton of pig iron made does not necessarily mean poor gas. Two analyses of the gas from the Frodingham Furnaces show 27.3 and 26.6 per cent. of carbonic oxide gas, with 1.4 and 3.1 per cent. of hydrogen respectively. The thermal value is 96.7 and 99.3. That will show you that the chemistry of the furnace is fairly indicated by the analysis given at the end of the paper, and that the power of the gas depends more upon the various actions taking place in the furnace than on the amount of the fuel. It is not necessary because you are using a low quantity of fuel to suppose you have got a very low quality of gas. I have known furnaces where 25 and 28 cwt. of coke per ton of iron has been employed, and I don't find that the quality of the gas is so good as in the case of furnaces in the North, where they have been using 19 cwt. That point has not as yet, I think, been fully appreciated. I may say that we are very largely occupied just now in the application of the gas engine for the driving of blast engines. We have not actually tried it yet, but so far as we have gone we see no difficulty, and we hope shortly to be able to realise the idea.

Mr. W. BROOKS: As one who is interested in the question of power—having charge of steam boilers—I have great pleasure in proposing a resolution of thanks, and I may say I look forward to the time when we can dispense with steam boilers, and when we can generate power for driving our machinery without the constant risk and rapid deterioration inseparable from the present very costly method of steam generation.

Mr. SILVESTER: I have much pleasure in seconding, and I hope the paper will induce a thoughtful study of the subject, and that it will lead to good results.

The resolution was carried unanimously.

The second Meeting of the Session was held at The Institute, Dudley, on Saturday, January 7th, 1899.

The Vice-president (Mr. H. SILVESTER) took the chair, and there was a good attendance.

The minutes of the previous Meeting were read, adopted, and signed.

THE PRESIDENT then delivered the following Address :—

## ADDRESS BY THE PRESIDENT,

Mr. H. LE NEVE FOSTER.

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It is an honour in any sphere of life to be chosen by one's friends as their leader, and it would appear that while the honour is greater the responsibility is also greater with the numbers who have chosen such leader. I, therefore, ask for your sympathetic indulgence in the work I have undertaken in this important Institute.

I am persuaded that this Institute should be a most powerful factor in the economies of the South Staffordshire Iron and Steel Trade, and in order that this, its most desirable object, should continue, it behoves us to learn and realize the importance of what is going on in other metallurgical centres. We there find that when their success is greatest, so interchange of ideas, mutual confidence, and mutual support towards a common end, is also greatest.

It is recognised that many matters are of common interest, and united action is necessary in order that they may be most successfully dealt with. This, I take it, is the precise and fundamental object of the South Staffordshire Institute of Iron and Steel Works' Managers, and I trust no effort on my part will be wanting to further it.

Our Institute has had a most honourable past. It has been the means of bringing together theory and practice. Some most valuable papers have been read at its meetings, and its influence on the large number of practical men who have attended these meetings must, I am sure, have been of a beneficial and enduring character.

I feel conscious of increased difficulties in my position, when I am called upon to address you as your president. I am reminded of the masterly address of my predecessor in this chair, in which he, among other matters, dwelt so ably on the claims of labour and capital, a matter which, fortunately, has been recently less prominent than it was. I cannot say I hope to emulate my predecessor in the eloquence which he brought to bear upon that important subject; but I can, nevertheless, offer for your consideration to-night, some points bearing upon a matter which is no less important, and which, perhaps, has some advantages over it because it appeals to the future, namely, the subject of the present and future aspect of the manufacture of steel in this district.

On the mention of steel I may, perhaps, be allowed to digress in order to humbly bear testimony to the loss the whole world has sustained in the death of that king of inventors, Sir H. Bessemer. The influence of

the Bessemer process in the history of the world will never be assessed ; it has accelerated the march of civilisation enormously. Sir H. Bessemer passed away on March 15th of last year, and it is our satisfaction that he died full of the honour accorded to him by his grateful country and by a grateful world.

As a result of his process we find it stated, on the authority of Mr. Andrew Carnegie, that steel can be now bought in the United States for less than £3 per ton, and we know from the testimony of the import tables in our Board of Trade returns, which show an increased importation in this country, that this steel, etc., is being sent carriage paid into this country at considerably less than the English market price, and I have no doubt that many of the gentlemen here present to-night have not only seen but used both this American pig iron and steel blooms. This is a matter which concerns us. What are we as steel producers to do in face of such competition? One of the most interesting papers read during the last session was by Mr. A. Head on this subject. It pointed out, what many of us have yet to learn, that cheap labour is not always a blessing. America with her dear labour has been able to produce cheaper than we can, one of the principal reasons being, as Mr. Head so ably points out in his paper, that the American invariably adopts labour-saving appliances, and so has found one of the great secrets of success, namely, that capital is cheaper than labour ; in other words, machinery must take the place of brute force.

I am no advocate for cheap labour, and as our workmen get better educated, we shall find they will not be content to do the work that can be done better and more efficiently by machinery ; that it is to their ultimate advantage to employ labour-saving appliances, and that the appliances instead of decreasing the value of labour really increase it, as they not only obtain higher wages, but are able to buy cheaper, and so obtain a greater value for those wages.

I understand we shall have a most interesting paper this Session dealing with some American appliances, more especially connected with conveying and transportation of materials. It is a truism often forgotten, that the success of an operation is the economy which can be effected by it.

As we know, cheap coal often means extravagant methods of using the same ; where coal is dearer you will always find the most economical methods of consuming it, and getting the greatest value out of it. Nature has blessed this country with cheap fuel, but it would appear that, equally with cheap labour, this blessing is in a transition state.

If £3 per ton is an actual price for hematite steel in America, why cannot steel be made in this district at the same price, when the slag yielded, can, as you are aware, be utilised and sold from 30s. to 35s. per ton, whereas, in the case of the manufacture of hematite steel, as chiefly manufactured in America, the slag is not only valueless, but also

has to be dumped on valuable land? It is entirely a question of capital expenditure, and large producing capacities, joined together with the best attainable technical knowledge and skill, as well as a perfect system of detail cost, not only of wages, but dealing with yields, so that the smallest leakage may be detected and rectified at once.

In discussing the advantages of Staffordshire for steelmaking purposes, we must first of all consider the facilities that exist for obtaining the necessary raw material. First the ores, fuels, and fluxes. Secondly, the character of the iron produced, Thirdly, and not least, the markets for the finished material. In addition, we may consider the possibilities of further advancement in other districts.

#### IRON ORES.

Economical supplies of iron ore are most certainly a very potent influence in determining the situation of works. Cost of transit, as well as economical methods of mining, loading, and handling must all be taken into consideration. The ores of Staffordshire are too expensive to mine, and too valuable, to manufacture into a cheap pig, and they readily find a market, hence I do not include them as being suitable for the manufacture of cheap steel. (See Table I. at end.) In Northamptonshire and Oxfordshire we have very large deposits. As the bulk of these deposits are quarried and not mined, they are very cheaply raised, and can therefore be delivered in Staffordshire at a comparative small cost. The tap-cinder of the Staffordshire ironworks may also be considered as iron ore, and what, as you are aware, was a waste product a few years ago, has now a considerable value, not only from its iron contents, but also for the percentage of phosphorus it contains. Germany has for many years past recognised the value of tap-cinder, and large quantities have been exported to that country.

With these ores we have the materials for making a most suitable iron for basic steel manufacture, the average analysis of which is as follows:—

|                |     |     |                 |
|----------------|-----|-----|-----------------|
| Silicon ...    | ... | ... | ·630 per cent.  |
| Phosphorus ... | ... | ... | 3·050 per cent. |
| Sulphur ...    | ... | ... | ·08 per cent.   |
| Manganese ...  | ... | ... | 1·35 per cent.  |

Limestone deposits are found in Staffordshire, Shropshire, and Derbyshire, suitable for ironmaking. The Stourbridge fire-bricks are known all over the world for the excellence of their quality. I can also inform you that large deposits of dolomite exist in Shropshire, and that works are being erected there for the manufacture of basic material suitable for lining the converters, etc.

#### FUEL.

The coalfields of South Staffordshire are the most important in Central

England, and the thick coal has been a great source of wealth to this district. Trials have been made from time to time to utilise the small coal of this district for coke making, but, as far as I am aware, not with any great success. Here is an opportunity, and any one who will overcome this difficulty will confer a great benefit to this district, and no doubt reap a good reward.

The bulk of the coke used comes from either South Yorkshire, Durham, and North and South Wales, and these are mixed with raw coal according to circumstances.

To an assembly like this Institute I need not point out the large consumption of steel in various forms in the Midlands. I am informed, on good authority, that over 3,000 tons of steel are imported into this district weekly, for various purposes, and these naturally have to come from long distances, and pay heavy railway dues. I ask, why should not this be manufactured in Staffordshire, from basic pig? You have the market at your door for the finished material, as well as the raw material close at hand. I am quite aware I shall be told that "sea board" is necessary, so as to save, as far as possible, the heavy railway dues. That may be perfectly right if you are entirely dependent on export trade, as well as on foreign ores, but in this district we depend on English ores, as well as having a large, and, I think I may say, increasing local market for the steel produced. The future of Staffordshire depends to a great extent on the close proximity of the Northamptonshire and Oxfordshire iron ore deposits. In using the word proximity, I do not so much mean the actual distance as a much more important factor—the actual cost of transit. Can this be reduced? I think I can answer this question in the affirmative. In the first place, the bulk of the ores are brought into Staffordshire in the raw condition. I would suggest, as worthy of consideration, that economical calcining stoves should be erected at the mines, and the ore calcined before being despatched. The cost of calcining at the mines would be identically the same as at our works in Staffordshire; there would be a slight increase in cost of fuel, but this would be so small that it need not be taken into consideration. The advantage gained would be practically a saving of nearly 30 per cent. on the carriage of these ores.

Mechanical means for concentration of poor grade ores is a subject worthy of consideration, and if this can be applied to Northamptonshire and Oxfordshire ores it would prove of great service to the Staffordshire ironmaster, as there would be a considerable saving in the railway freights. There would be also a corresponding saving in the number of wagons employed, as well as in handling less material at our works, a small detail that need not be despised. Whilst dwelling on this subject I cannot help pointing out that our manufacturers are greatly

handicapped in comparison with the Americans with regard to railway rates. In America the cost of transporting raw material is about one-sixth of a penny per ton per mile; in this country the rates are seldom below  $\frac{1}{4}$ d. per ton per mile, that is to say, the Americans can carry raw material 300 miles for the same price we should have to pay for the same material to be carried 100 miles.

The lessening of the rates for raw material should have the serious consideration of our railway managers. I have no hesitation in saying that a slight reduction in the rates on raw material would have the effect of largely increasing their revenues, and so foster trade in this important district, and to a great extent prevent the importation of American iron and steel. It is on the raw material we want relief, not on the finished product, as advocated by a small section in one particular branch of the iron trade.

There can be no question that if steel is to be made in Staffordshire it must be made from basic iron, as the cost of either importing or making hematite iron is quite prohibitive commercially, except for some small specialities.

There are, as you are aware, two well-known processes by which this iron can be converted into steel. For a small installation of not exceeding 1,000 tons per week, I should chose the well-known Open-hearth or Siemens process as being the most suitable and economical; if, however, it was intended to manufacture on a large and economical scale, say 1,500 tons to 2,000 tons per week, I should adopt the Bessemer method, as being more suitable; both processes are capable of making uniform and reliable steel. In the cheap production of steel, every possible economy must be utilised. The first consideration, after the cheap production of iron at the blast furnaces, is the transportation of the metal, whilst still molten, to a mixer; by this means not only are the labour and cost of fuel for re-melting saved, but also quite as important an economy is effected, viz, the obtaining of a much more uniform and reliable quality of metal, small deviations in quality being rectified by the well-known law of averages, consequently a more uniform quality of steel is obtained, the metal is free from sand, and the percentage of sulphur appreciably reduced. To an assembly such as the present I need not dwell upon the advantages of eliminating our old enemy sulphur.

I need not dwell upon the enormous advances that even I have seen in the production of steel. Only looking back a few years, I can quite remember when a 20-ton cast of metal was considered a great thing; now 50-ton casts are quite as common. Ingots weighing one ton each were considered large, now five and six-ton ingots are every day practice. Again, ingots were cast and allowed to cool and were afterwards re-

heated and hammered into blooms or billets of suitable sizes for rolling down. Compare this with the ingenious methods of to-day:—The ingot is cast and allowed to solidify in a soaking furnace, and so utilise its own initial heat, it is then cogged down by means of massive cogging mills, and rolled direct into many requirements.

The handling is reduced to a minimum by the use of an elaborate system of live rollers and turning gears, and labour is reduced to a minimum. Mechanical means are now used for one and every operation, and by this means the cost of production has gradually decreased. If we are to make steel economically, it must be made by large installations and mechanical labour-saving appliances, commencing with ore raising and not finishing until the steel leaves the works.

I do not think that the value of phosphorus in the pig iron is yet fully appreciated, and to-day one of the most important factors in the economy of steel manufacture is that basic slag has now become a commercial commodity and has a good market value. In the process of grinding this slag a considerable quantity of steel is recovered by means of magnetic separators, which more than pays for the actual cost of grinding; in fact, in some of our acid works the slag is being ground simply to separate and recover the steel therefrom. Mr. Sidney Thomas made a statement some 15 or 16 years ago which was ridiculed at the time, viz., That, taking the cost of production into consideration, steel will be the bye-product and phosphorus the main object.

I can tell you that the time has now come, when this statement comes very near the truth, and in our natural progress we are proving the value of basic slag. Its value has increased, though for a considerable period it was considered it had no value whatever. Its true value is hardly yet recognised, and large quantities have been exported. One of our highest agricultural authorities states that every ton of basic slag exported out of the country at £2 per ton is a loss of £5 per ton to the community at large. From this you will see that by utilising the phosphoric ores we are preserving the national mineral wealth of our country two-fold. First, we extract the iron; secondly, the phosphorus, which is returned to the soil in a form that it can be assimilated. This opens up a very large field for the future development of waste material, and no doubt will play an important part in the future economy of South Staffordshire iron manufacture.

Sir William Crooks, F.R.S., in his able address before the British Association dealt very considerably with the important question of the future supply of bread to the inhabitants of the British Isles, and also the several available sources of both nitrogen and phosphates, but I do not think he mentioned that iron and steel makers contribute in any way towards the production of these fertilizers, and I take this opportunity of pointing out that we have large sources of this material at our disposal.

Last year, in the manufacture of pig iron alone 17,552,430 tons of coal were consumed, and presuming that each ton of coal would produce 2 c. lbs. of sulphate of ammonia, we have equal to 150,000 tons of sulphate of ammonia per annum at our disposal. As manufacturers it concerns us. Are we able to preserve this ammonia at a cost of not less than the selling price? You know that it has been done to a certain extent in some of the Scotch furnaces. I have been informed that at one of the large Scotch works, which consists of six blast furnaces, two of them being employed making hematite and the other four furnaces making basic iron, that they have been able to produce from 30 to 40 tons of sulphate of ammonia per week, as well as 45,000 gallons of tar, 165 tons of pitch, and about 25,000 gallons of oil.

This latter oil is used for creosoting timber, and for Lucigen or Wells lamps, etc. The bulk of the gas dealt with is about 60,000,000 cubic feet per day, the main gas collecting tube being 8 feet diameter.

I have already pointed out to you how we preserve the phosphates in the basic slag, and now we are also able to conserve some of the nitrogen, so that even Sir William Crooks must admit we are doing our share, not only as bread winners but bread makers.

The utilisation of blast furnace gas is a problem that has the consideration of a number of scientific gentlemen, and we have already had a most valuable paper dealing with this subject in a very practical form, showing that these gases, which were allowed to go to waste at the top of the furnaces a few years ago, and are now only partially used for generating steam under boilers, can be more economically used as a motive power in gas engines. It was naturally considered that these gases were too poor in combustible matter to be of any service, but Mr. Thwaite has now shown us how these gases can be utilised. The ideal iron and steel works of the future will generate all the necessary power from waste blast furnace gas (after all the bye-products have been recovered), not only for its own blowing engine, but also the Bessemer blowing engines, and possibly electric heating furnaces, to say nothing of the electric light and other electric power required for driving small motors.

Everything must be utilised; even the despised blast furnace slag now finds a ready market for railway ballast and road making, whilst in Germany it is granulated and ground, forming a cheap substitute for Portland cement. It has also been made into bricks for paving and building purposes, as well as manufactured into slag wool, which makes an excellent non-conducting material for covering boilers and steam pipes. It was also used for the manufacture of glass bottles and slag-ware, but these last two were not successful.

From Table II. you will see that in 1873 there were in blast 683 furnaces, producing 6,566,441 tons pig iron; whilst in 1897 there were

only 380 furnaces, which produced 8,796,465 tons; that is to say, each furnace in 1873 averaged 9,320 tons, or about 180 tons per week; whereas in 1897 each furnace averaged 23,148 tons, or over 445 tons per week.

These figures fully illustrate the advances made in the manufacture of pig iron. Furthermore, the returns for 1897 show the largest quantity of pig iron ever produced in one year in Great Britain, and I shall be surprised if the make for this year does not exceed even this record. This most certainly argues well for the future of the iron trade. To produce this quantity of pig iron no less than 21,327,013 tons of iron ore were used, as well as 17,552,430 tons of coal; in other words, one-twelfth the total quantity of coal raised in Great Britain was used for the manufacture of pig iron. If by scientific methods we are able to recover only a portion of this enormous quantity, this and other like societies will not have laboured in vain, because it is by the discussion of these important questions that we bring more thought to bear upon them. If we are able to recover only a portion of this enormous quantity we shall have achieved something that will benefit the nation at large.

The utilisation of British ores in the place of foreign ores gives employment and helps to support our own population, instead of affording employment to the foreigners. All these are worthy of consideration. In spite of this great progress, the Americans are greatly ahead of us in blast furnace practice. I must admit they have excellent ores, etc., to deal with. The Duquesne blast furnaces were, I believe, designed to produce 500 tons of pig iron per day per furnace, or 3,500 tons of pig per week, or the four furnaces 14,000 tons per week. These furnaces have more than realised expectations, for they produced during month of October last an average of 599 tons per day per furnace, the coal consumption being only 1,800 lbs. per ton pig iron; this low consumption of fuel is accounted for by the fact that they have exceptionally rich iron ore.

It may be interesting to state that each of the furnaces cost over £130,000, or at a total cost for the installation of four furnaces over £500,000.

To give you some idea of the quantities of material consumed in these four furnaces in 24 hours, I may tell you it would take no less than 60 train loads, each train averaging 180 tons, that is to say, a continuous string of wagons over five miles; and furthermore forty such furnaces as these, in full blast, would do as much work as the 380 furnaces now in blast in this country. It must not be supposed for one moment that I advocate the advisability of employing all large furnaces entirely; for instance, in the manufacture of cold blast iron, for which this district is so noted, the employment of small furnaces is most desirable.

TABLE I.

The Output of Iron Ore in Staffordshire, Northamptonshire, and Oxfordshire, 1880 to 1897.

| Year. | OUTPUT.                      |                                      |                                             |
|-------|------------------------------|--------------------------------------|---------------------------------------------|
|       | Stafford-<br>shire.<br>Tons. | North-<br>ampton-<br>shire.<br>Tons. | Oxfordshire.<br>Tons.                       |
| 1880  | 1,761,466                    | 1,550,103                            | 8,360                                       |
| 1881  | 1,769,322                    | 1,270,545                            | 8,614                                       |
| 1882  | 2,022,529                    | 1,333,085                            | 12,733 (including Rutland)                  |
| 1883  | 1,797,244                    | 1,290,087                            | 41,645     "     "                          |
| 1884  | 1,873,745                    | 1,279,783                            | 32,885     "     "                          |
| 1885  | 1,829,571                    | 1,160,000                            | 25,376     "     "                          |
| 1886  | 1,591,055                    | 996,440                              | No return given.                            |
| 1887  | 938,018                      | 935,473                              | "     "                                     |
| 1888  | 1,689,768                    | 1,066,746                            | "     "                                     |
| 1889  | 1,262,678                    | 1,257,080                            | 119,781 (including Rutland and Wilts)       |
| 1890  | 1,224,510                    | 1,278,381                            | 143,339     "     "                         |
| 1891  | 1,071,121                    | 1,043,541                            | 144,578     "     "                         |
| 1892  | 1,040,640                    | 1,120,365                            | 86,229 (including Rutland)     "            |
| 1893  | 808,779                      | 719,071                              | 133,616 (including Rutland and Wilts)       |
| 1894  | 846,515                      | 1,130,773                            | 155,407 (incl'g Rutland, Wilts, & Somerset) |
| 1895  | 862,147                      | 1,082,252                            | 70,787 (including Rutland)                  |
| 1896  | 933,742                      | 1,263,650                            | 94,101     "     "                          |
| 1897  | 926,521                      | 1,264,915                            | 78,868     "     "                          |

TABLE II.

Number of Blast Furnaces in operation in Great Britain, the Quantity of Pig Iron produced, and the Quantity of Ore and Coal used in its production for each year, from 1873 to 1897.

| Year. | Furnaces in Blast. | Pig Iron made. | Iron Ore Smelted. | Coal used. |
|-------|--------------------|----------------|-------------------|------------|
|       | Number.            | Tons.          | Tons.             | Tons.      |
| 1873  | 683                | 6,566,451      | 16,820,035        | 16,718,532 |
| 1874  | 649                | 5,991,408      | 15,854,077        | 15,292,201 |
| 1875  | 629                | 6,365,462      | 16,559,753        | 15,645,774 |
| 1876  | 585                | 6,555,997      | 17,813,818        | 15,598,381 |
| 1877  | 541                | 6,608,664      | 18,250,110        | 15,342,445 |
| 1878  | 498                | 6,381,051      | 17,299,781        | 14,112,305 |
| 1879  | 497                | 5,995,337      | 15,797,080        | 13,117,411 |
| 1880  | 567                | 7,749,233      | 21,086,740        | 16,982,629 |
| 1881  | 565                | 8,144,449      | 20,249,263        | 17,484,990 |
| 1882  | 570                | 8,586,680      | 21,249,462        | 17,796,301 |
| 1883  | 552                | 8,529,300      | 21,013,275        | 17,775,000 |
| 1884  | 476                | 7,811,727      | 18,887,505        | 16,077,800 |
| 1885  | 434                | 7,415,469      | 17,937,966        | 15,287,527 |
| 1886  | 399                | 7,009,754      | 17,297,483        | 14,249,715 |
| 1887  | 405                | 7,559,518      | 18,363,583        | 15,304,188 |
| 1888  | 423                | 7,993,969      | 19,152,074        | 16,131,267 |
| 1889  | 445                | 8,322,824      | 19,683,948        | 16,766,694 |
| 1890  | 414                | 7,904,214      | 19,213,916        | 16,168,538 |
| 1891  | 376                | 7,406,064      | 18,518,192        | 15,373,711 |
| 1892  | 362                | 6,709,255      | 16,344,454        | 13,860,161 |
| 1893  | 327                | 6,976,990      | 16,620,653        | 13,806,728 |
| 1894  | 325                | 7,427,342      | 17,803,908        | 14,884,800 |
| 1895  | 344                | 7,703,459      | 18,629,337        | 15,224,517 |
| 1896  | 373                | 8,659,681      | 21,204,284        | 17,114,374 |
| 1897  | 380                | 8,796,465      | 21,327,013        | 17,552,430 |

Mr. SILVESTER (Vice-president): I believe it is an unwritten law, which might sometimes be abolished with advantage, that presidential addresses are not discussed, and therefore I rise, not with the intention of criticising, but of expressing my appreciation of the admirable survey which Mr. Foster has given us of the condition of the iron and steel trade in the Midlands, and the favourable and unfavourable circumstances which have to be considered in judging of its future. He opened his address, I was very glad to notice, with a eulogy of the work that this Institute was capable of doing, and has done, and towards the close of his address he still further emphasised the benefits to be derived from the papers and discussions that periodically take place. In recent years considerable attention has rightly been given by the State to technical education, and in this direction a reference to the "Proceedings" cannot fail to show the great educational value of the Institute to South Staffordshire. Most of us, connected directly or indirectly with the iron and steel trades, must have experienced these benefits.

Another feature of the address that pleased me was the absence from it of a pessimistic tone as regards the future of the Midland iron trade. We are so accustomed to read the epitaph of the trade in leading articles and letters whenever a little American steel or pig iron is delivered into the district, that it is refreshing and inspiring to listen to opinions of an opposite character, backed up by a considerable amount of evidence as to why the iron and steel trade should continue to be remunerative in South Staffordshire. Our President has pointed out to us what may be done to save the carriage of useless material from the mines to the blast furnaces, and the calcination of the ore raised in Oxfordshire has already been commenced by some companies.

Statistics of the enormous output of some American blast furnaces were also brought before us, and although we may not hope to emulate their yields, they must act as a spur, urging us to improve our practice.

I have pleasure in moving a vote of thanks to Mr. Foster for his interesting address.

Mr. H. PILKINGTON: It gives me very much pleasure to second the vote of thanks. We have had a very able address, and our President has reviewed the possibilities which remain for Staffordshire. I have never myself been a pessimist as regards Staffordshire; in fact, I have sometimes been called over the coals for adopting an optimistic tone. I believe Staffordshire has at command some of the cheapest sources of fuel and of pig iron in this country, and is in respect of other materials for iron and steel making as well off as any other district. We cannot, it is true, produce pig iron like I saw it produced in Alabama for 21s. per ton at the furnace; but some of us are getting nearer in that direction than formerly. The address is worthy of the occasion and worthy of the Institute.

Mr. J. W. HALL: I enjoyed very much the part of the presidential

address I did hear, and was exceedingly sorry that I missed the part in which Mr. Foster appears to have referred to the utilisation of by-products, but my train was late. I congratulate Mr. Foster upon the great success which I am sure his address will have.

Mr. Jos. COLLEY : I have enjoyed the address very much indeed. As to the high tribute which the President has paid to Sir Henry Bessemer, I remember as far back as 1863 being very much fascinated by a little Bessemer plant we had at Tudhoe, when we used to convert 30 cwts. of hæmatite into steel. The President referred to 20-ton steel furnaces ; we have now got to 40 tons in one cast. We have splendid opportunities in this district—cheap fuel and capital lime—for making steel by the basic process, and we must try to improve our works in every possible way, and although we may not be able to manage things so cleverly and get such enormous outputs as the Americans, yet we ought to progress so as not to be altogether left behind. I have great pleasure in supporting the vote of thanks to our President, for we have had a most able paper. It has been a great pleasure to me to listen to it, and it has caused me to look into the matter both in a theoretical and practical way, and instead of “resting upon our oars” be determined to advance with the times.

Mr. W. B. RUBERY : To choose a subject for a presidential address is a very difficult matter. It is quite cheering to find that the pessimistic tone is absent. We can certainly congratulate our President, for it is an address which will be read generally with the greatest pleasure.

The vote of thanks was then carried by acclamation.

THE PRESIDENT : I thank you very much for the kind way in which you have expressed your commendation. I have only done what is my duty, and I trust if anything comes from this it will be a determination to help forward the trade of South Staffordshire. Towards that end there is one thing we can all do, and that is we can introduce new members. I trust every member here to-night will do what he can to get one or two of his friends to join. In pointing out what America has done, I do not for one moment think that we can do exactly the same in producing iron, but I should like to point out that the 1897 output was the largest quantity of iron ever produced in this country ; so that does not look as though the iron trade in Great Britain was not in a healthy state ; and I believe 1898 beats 1897. I don't think the iron trade of Great Britain is going back, and I am perfectly certain that South Staffordshire is not going back. I thank you for your kind expressions.

The third Meeting of the Session was held at The Institute, Dudley, on Saturday, the 11th February, 1899.

Mr. LE NEVE FOSTER (President) occupied the chair.

The minutes of the previous Meeting were read, adopted, and signed.

Messrs. W. Nock, Jun., George Higgs, W. W. Attwood, and John Bate were elected members of the Institute.

On the proposition of Mr. RICHARD EDWARDS, seconded by Mr. W. YROMANS, a vote of condolence was passed with the wife and family of the late Mr. Edward Trow.

Mr. E. D. NICHOLSON then read the following paper :—

## CHILLED ROLLS, AND WHY THEY BREAK.

By E. D. NICHOLSON.

This paper was originally written at the request of the Council about four years ago, but for several reasons reading was postponed, being again asked to read it, I have much pleasure in so doing.

As the manufacture and destruction of chilled rolls has so recently been before this Institute it may appear somewhat inopportune at so early a time to re-open the question; but as the main issues of such an important matter became to a great extent obscured, I feel that no apology is needed for again making it, to a great extent, the text for this paper.

The points I propose to confine myself to as far as possible are—

- 1.—That the best chilled rolls are made in Staffordshire.
- 2.—That the best pig iron for the manufacture of chilled rolls is produced in Staffordshire.
- 3.—Why chilled rolls break.

I consider that I am justified in claiming that the best chilled rolls are made in Staffordshire, for the very simple reason that sheet and plate makers buy them and buy largely, and that more chilled rolls are made in Staffordshire than in any other founding centre. Naturally, Staffordshire firms buy them; some, no doubt, from patriotic motives, or a desire to do their friends and neighbours a good turn. But why do the South Wales, Lancashire, Cleveland, Scotch, and other firms in the United Kingdom buy them?

Why, in the face of hostile tariffs, heavy freightage, etc., do the Belgian, French, German, Russian, Italian, Spanish, and even Turkish and Chinese iron manufacturers buy them? It is not patriotism or fraternal love. It is a matter of hard cash. It is because they are the best. The Staffordshire rolls have a better face, keep a good face longer, and are stronger and more economical in the long run than those made elsewhere. I am not aware that any are exported to the United States, but I believe that if the high tariff could be done away with, the Staffordshire roll founders would be able to compete successfully with their American brethren. Such is the unreliable character of the American roll, I am told, that it is common practice where mills are not too large to have a pair of rolls, housings, etc., all bolted together complete, is

that in case of failure the old set can be lifted out bodily and the new put in without serious loss of time.

On the Continent, the great trouble, besides breaking, is what we commonly call shelling or spawling, and although rolls of home manufacture are made and supplied at a very much lower price than that at which Staffordshire rolls can be procured, the great majority of the best firms patronise to a large extent the Staffordshire article; therefore, we may take it for granted that the Staffordshire gives the greatest satisfaction and is the cheapest in the end.

Other reasons why the best rolls are made in Staffordshire are: That this county may fairly claim to be the home of the chilled roll trade. I do not feel justified in saying that such rolls were first made here, as it is more than probable that the Forest of Dean produced chilled rolls in the very early days of sheet making; but it is beyond doubt that for over 70 years at least their manufacture here has been to a large extent a monopoly. No doubt some of our members will feel a pleasure in enlightening us on this head.

It must also be borne in mind that until late years the art of casting chilled rolls has been more or less what I may call (for want of a better term) a negative art, that is to say, a caster did not know why certain brands or numbers did not suit, but as it was found from practical experiment that they would not, they were religiously eschewed, and ultimately the range of irons was narrowed down to those that there was every probability would suit; this was handed down from father to son, friend to friend. Others, by a keen practical observation and having a turn for experiment, acquired the requisite knowledge. Am I saying too much when I say that 25 years ago it would have been almost impossible to find a practical roll caster who would be able to state the amount of chill to be expected from a pig—without first trying it—unless he knew the brand and the precise conditions of its manufacture, *i.e.*, hot or cold blast? Now, there are not only men in the trade, but blast furnace managers, who will, on a complete analysis being shown them, be able, conditionally that the iron is re-melted properly, to say to a very near point the amount of chill that can be expected without seeing the pig at all. The operation of melting again requires great care; roughly speaking, an oxidising flame was, and is, the enemy. This was not known, but the men who had charge of the furnace knew that if the fire was not worked in a certain way, or if doors were left open at a particular time, trouble would ensue. It must not be inferred that I cast any reflections upon the old men but the reverse, because these men, more of whom are still in this district than elsewhere, and who strove and plodded hard to acquire the requisite knowledge of selection and melting, are with us now, and are a fund of knowledge of technical details other districts do not possess. It will also be found that the greater proportion of the men actually employed in the same trade in

other centres are Staffordshire men, or acquired their information here. Consequently, Staffordshire possesses more men thoroughly well up in the actual details than other districts which are handicapped to a greater or less degree.

I will not go to such an extent as to say that other districts cannot and will not be able to make as good a roll as Staffordshire, but I do not think there is a roll maker in the United Kingdom making first-class rolls that does not use Staffordshire and Shropshire cold-blast irons.

As other reasons which may be adduced will perhaps more fitly come under point No. 2, it will be as well now to consider it, but before doing so I must say that egotism will not suffice to keep Staffordshire going. She has a great deal to learn, and can make bad rolls, but I maintain that she has not been caught up, much less beaten, and is much better equipped than her opponents for the race, if she will only avail herself of her opportunities while there is time.

In considering that the best pig iron for the manufacture of chilled rolls is produced in Staffordshire [by the term Staffordshire I also include Shropshire, as for all practical purposes the cold-blast pigs of each are identical] it will be as well to dwell for a short time upon the constituents of a roll, and some of their peculiarities.

A chilled roll is composed of iron, silicon, phosphorus, sulphur, manganese and two, if not more varieties of carbon. The following figures show how different are some of their properties:—

|                  | Specific Gravity. | Specific Heat. | Melting Point.         |
|------------------|-------------------|----------------|------------------------|
| Cast Iron        | 7.50              | 1298           | 2000°F.                |
| Manganese        | 8.00              | 1441           | Highest heat of forge. |
| Sulphur          | 2.00              | 1884           | 239°F.                 |
| Phosphorus       | 1.77              | 1887           | 112°F.                 |
| Carbon (diamond) | 3.50              | 1468           |                        |
| „ graphite       | 2.20              |                |                        |
| Silicon          | 2.50              |                |                        |

Authorities : Dr. Percy, D. K. Clark, J. A. Phillips.

The specific heats do not vary to any great extent, but the specific gravities and melting points do ; therefore, it is no wonder that these differences cause great disturbance and set up strains in cast-iron which the ironfounder would be glad to avoid. There is no doubt a great deal to be said in favour of eliminating, as far as possible, the different metalloids from a casting requiring great strength when heated, but the roll maker has to make not only a casting but a tool, and a highly finished one at that.

Other features perhaps not always borne in mind are : That cast-iron in a molten state is probably of a greater specific gravity than when solid and cold ; that iron, manganese, and probably silicon, expand the

moment they solidify, exactly the same as water expands upon becoming a solid as ice. Phosphorus and sulphur behave in a directly opposite manner. I mention these simply to show some of the difficulties a roll founder has to contend with, as it is not simply melting metal and pouring it in a mould (or, as a man who had been through a cannon foundry, on telling a friend how it was done, said, "they get a round hole and poured brass around it"), but it is an operation requiring great care, first in selecting the pig, afterwards in melting it, so that the final result is a well-balanced casting, not one with one constituent getting supreme control and causing disaster.

A chilled roll for hot rolling should have sufficient strength when heated to do its work :—A clear hard surface free from all pin holes, cracks, or other blemish, depth of chill that will allow of its being turned, say, every week until it has done a fair quantity of work ; and the chilled portion must not be of such a nature as will shell off under fair treatment before the roll has worn out ; on the other hand not be too soft and wear out too soon.

Now these requirements are antagonistic, because a roll made simply for strength under heat would not have the requisite hardness or depth of chill, its composition probably would not include much, if any, phosphorus (which gives fluidity), and thus prevent a clear surface being obtained ; sulphur would not be allowed because it makes iron hot short, but with it would go the hardness ; manganese you may say should be substituted, but then the face would be so hard that it would shell off. Cast iron, we are told, to have its maximum strength must contain about two per cent of silicon, but iron containing this quantity of silicon will not chill to any appreciable extent unless the sulphur is far above the amount that can be allowed in a chilled roll. Carbon I am almost afraid to speak of ; when we considered that there were only two kinds—graphite and combined—the question was complicated enough, but we are now told that there is graphitic, combined, hardening, and tempering carbon in the same casting, the complexity is much greater, and I must honestly confess lack of knowledge to venture to give an opinion on it. Altogether we have the elements of a very fine quarrel only requiring a given amount of heat in the wrong place to set it going. Unfortunately it too often comes off.

In more operations of this life than roll casting, when each party or thing cannot have the upper hand, the only solution is a compromise ; or in other words a balance is struck between the contending parties or elements. A good chilled roll is a casting which contains component parts well balanced, that is, the properties of each constituent are up to a certain point, neutralised by that of another one.

For the purpose of making chilled rolls, what is known as a close No. 5 cold-blast Staffordshire pig is the nearest approach to an ideal pig for the purpose ; it is of course well known that other cold-blast brands of

Wales and Yorkshire are almost as good, but even if for the moment we admit that they are, owing to their great repute for other purposes, such as cannon casting, locomotive cylinders, castings requiring great strength, and the manufacture of the famous brands of bar iron, the price is higher, and it is open to question whether the roll maker who buys them is not often paying something for the reputation. I do not for a moment wish it to be thought that I desire to depreciate the value of these irons. For their own special purposes, perhaps, they are unrivalled; but for the moment I am considering them from a rollcaster's point of view.

The analysis of a good No. 5 Staffordshire cold blast pig, I make to be as under:—

|                  |     |     |     |     |       |
|------------------|-----|-----|-----|-----|-------|
| Silicon          | ... | ... | ... | ... | 1.110 |
| Sulphur          | ... | ... | ... | ... | .109  |
| Phosphorus       | ... | ... | ... | ... | .475  |
| Manganese        | ... | ... | ... | ... | .646  |
| Graphitic Carbon | ... | ... | ... | ... | 2.443 |
| Combined ditto   | ... | ... | ... | ... | .538  |

Now it is possible to attempt to prove any theory with a single analysis, but as I wish to get at, and lay before you something reliable, I have not pinned my faith to any single analysis. The percentages of silicon, sulphur, and phosphorus are the average percentage of 150 estimations of each metalloid made by a well-known analytical and metallurgical chemist, and represent a total bulk of about 3,000 tons of pigs over a period of three years. The percentages of manganese, graphitic, and combined carbons are not those obtained from so many estimations, but were taken over the same period, and are sufficiently comprehensive to put beyond all doubt any question as to their being a fair average.

The analyses are not of one particular brand, but comprise the whole of the cold blast brands of Staffordshire and Shropshire in fairly equal quantities, and if the cold-blast pig makers will undertake to supply pigs constantly to such an analysis, I will venture to say that no roll maker will refuse them. Blast furnace managers know their own troubles better than I can tell them, but roll makers have been told that they should give a standard to work to. I venture to respectfully lay before them the average analysis of their own pigs. None have been selected or omitted. The average includes good and bad, even some which have been put aside for other purposes than the manufacture of hot chilled rolls.

If I was asked for any improvements on the analysis, I should suggest that the silicon be kept down to 1 per cent., and the sulphur should not be over 0.08 per cent. If a roll maker wants to put more silicon or sulphur in his metal he can easily do it; but to lower a charge in either is sometimes impossible, and always troublesome. When this subject was last discussed here, Mr. Silvester gave analyses of old cold blast

and new cold blast irons. The new gave sulphur averaging '104 per cent., the old '082 per cent. Cold blast pig makers should give the matter of sulphur their very closest attention. It is quite as important to them as to the roll makers that the quality should be kept up, and I feel sure they are equal to it because they do now make pigs of as low sulphur, etc., as is wanted; but uniformity is needed, also more careful selection. And they should be in a position to say to the roll maker, "This lot is of such and such an analysis," thus saving a great deal of trouble to the roll caster, and enhancing the value of their own pigs.

As the analysis of the iron for making rolls has now been given, it may not be out of place to compare the same with the composition of an ideal roll recently laid before this Institute, which is as follows:—

|                  |     |     |     |     |       |
|------------------|-----|-----|-----|-----|-------|
| Silicon          | ... | ... | ... | ... | '650  |
| Sulphur          | ... | ... | ... | ... | '050  |
| Phosphorus       | ... | ... | ... | ... | '250  |
| Manganese        | ... | ... | ... | ... | 1'500 |
| Graphitic carbon | ... | ... | ... | ... | 2'865 |
| Combined ditto   | ... | ... | ... | ... | '635  |

Now it is beyond all doubt that a Staffordshire cold-blast pig and the pig from which the above casting is made will not melt satisfactorily together, or perhaps I had better say, give an average of the two in the casting (the pig is, I presume, a Swedish one). If a pig containing much over 0·7 per cent. of manganese is melted with a pig containing about 0·1 per cent. or less of sulphur, the product will contain less of both than the originals. Some time ago the old text book version that "Manganese makes iron white" came across my mind—I was trying to make some very hard rolls. Now it occurred to me that all I had to do was to put some ferro-manganese in and the job would be done; but much to my dismay the test bar, instead of showing more chill and a close hard back, was less in chill with a most beautiful grey kind back, and I had to revert to our old methods and leave the manganese until another day. As soon as opportunity served I tried it again, and if possible to solve the mystery had analyses taken of the different portions which were:—

Metal before adding Ferro.Manganese.

|                 |     |       |                |
|-----------------|-----|-------|----------------|
| Silicon         | ... | '900  | } Chill 1½ in. |
| Sulphur         | ... | '120  |                |
| Phosphorus      | ... | '520  |                |
| Manganese       | ... | '420  |                |
| Graphite        | ... | '540  |                |
| Combined Carbon | ... | 3'360 |                |

After adding enough of ferro-manganese to make the manganese equal, 1·5 per cent. analysis gave:—

|                 |     |       |                           |
|-----------------|-----|-------|---------------------------|
| Silicon         | ... | '950  | } Chill $\frac{7}{8}$ in. |
| Sulphur         | ... | '080  |                           |
| Phosphorus      | ... | '470  |                           |
| Manganese       | ... | '560  |                           |
| Graphite        | ... | '900  |                           |
| Combined Carbon |     | 2'930 |                           |

The analyses are perhaps not quite in accordance with each other, but are sufficient to show that manganese removes sulphur, and makes iron (that is cast-iron) greyer. If the operation was always carried on at the same speed and to the same extent, it would be invaluable for removing sulphur in the foundry, but it is not so. Sometimes the action will complete itself in the furnace, sometimes it goes on after it has been tapped out in the ladle, so that you cannot have any idea until the roll is on the lathe whether it is too high or too low, or in other words, whether there is too much chill or not. As our ex-president dealt more fully with this some time back I will not now dwell upon it, but the point I wish to lay stress upon is this: If the ideal analysis be adopted, chilled roll makers will not be able to use Staffordshire pigs, or if Staffordshire pigs are used the ideal roll cannot be made, at any rate of the analysis given. Which are we to do? To my mind the answer is quite clear. The ideal roll is only on paper, our rolls have for years been universally used, and it therefore follows that they are the best; if so, the material used in their manufacture also must be, and more pertinent reasons must be given for change than we have yet had.

Now, if one admits that a good casting is one with its constituents neutralised or balanced by each other (that is to say, their evil propensities), on comparing the analysis of Staffordshire pigs with that of the ideal roll one cannot fail to see that the manganese is master of the situation; its enemy, silicon, is not strong enough to curb it, and if ever a roll of such a composition gets to work its face will not last long, because it is too dense and hard for hot rolling. Granted that it is possible to produce such a pig lower in manganese to be of service, the silicon must be lower, the graphitic carbon also, or the iron would not chill to a sufficient depth. Can such a pig be produced at a price that will enable roll makers to use it? I fear not, and as long as we have a cheaper and better material at our own doors, why should we look abroad? It is principally a question of Hardness-Sulphur *versus* Manganese. Where has manganese borne the heat and burden of the day? We can point to sulphur under proper conditions, and in correct quantities, as giving satisfaction. It is the abuse, not the use, that has earned sulphur such a bad name,—nowhere more than in a foundry—but that is no reason why we should altogether discard it, at any rate until we have something more advantageous.

In considering why chilled rolls break, it will probably occur to some one to ask, What is the best chemical composition for a hot chilled

and new cold blast irons. The new gave sulphur averaging 104 per cent., the old 102 per cent. Cold blast pig makers should give the matter of sulphur their very closest attention. It is quite as important to them as to the roll makers that the quality should be kept up, and I feel sure they are equal to it because they do now make pigs of as low sulphur, etc., as is wanted; but uniformity is needed, also more careful selection. And they should be in a position to say to the roll maker, "This lot is of such and such an analysis," thus saving a great deal of trouble to the roll caster, and enhancing the value of their own pigs.

As the analysis of the iron for making rolls has now been given, it may not be out of place to compare the same with the composition of an ideal roll recently laid before this Institute, which is as follows:—

|                  |     |     |     |     |       |
|------------------|-----|-----|-----|-----|-------|
| Silicon          | ... | ... | ... | ... | 0.50  |
| Sulphur          | ... | ... | ... | ... | 0.50  |
| Phosphorus       | ... | ... | ... | ... | 0.50  |
| Manganese        | ... | ... | ... | ... | 1.500 |
| Graphitic carbon | ... | ... | ... | ... | 2.365 |
| Combined dirt    | ... | ... | ... | ... | 0.50  |

Now it is beyond all doubt that a Staffordshire cold-blast pig and the pig from which the above casting is made will not melt satisfactorily together, or perhaps I had better say, give an average of the two in the casting (the pig is, I presume, a Swedish one). If a pig containing much over 0.7 per cent. of manganese is melted with a pig containing about 0.1 per cent. or less of sulphur, the product will contain less of both than the originals. Some time ago the old text book version that "Manganese makes iron white" came across my mind—I was trying to make some very hard rolls. Now it occurred to me that all I had to do was to put some ferro-manganese in and the job would be done; but much to my dismay the test bar, instead of showing more chill and a close hard back, was less in chill with a most beautiful grey kind back, and I had to revert to our old methods and leave the manganese until another day. As soon as opportunity served I tried it again, and if possible to solve the mystery had analyses taken of the different portions which were:—

#### Metal before adding Ferro-Manganese.

|                 |     |       |                |
|-----------------|-----|-------|----------------|
| Silicon         | ... | 0.900 | } Chill 1½ in. |
| Sulphur         | ... | 0.120 |                |
| Phosphorus      | ... | 0.520 |                |
| Manganese       | ... | 0.420 |                |
| Graphite        | ... | 0.540 |                |
| Combined Carbon | ... | 3.360 |                |

After adding enough of ferro-manganese to make the manganese equal 1.5 per cent. analysis gave:—



roll? In the limits of the present paper I do not propose to say more than a few words on this head, as it is worthy of a paper in itself; moreover, until roll users can agree among themselves as to what is a good roll, it is useless to make any definite statement. Generally, roll users ask for a certain depth of chill. Some will say  $\frac{1}{4}$  in. to  $\frac{1}{2}$  in., others  $\frac{1}{2}$  in. to  $\frac{3}{4}$  in. for exactly the same kind of work; some like what is commonly called a painted or clearly defined chill; others, again, prefer the chill to mingle well with the back. In some cases the purchasers do not mind a little mottle; such rolls sent to another works would be at once rejected. Although depth of chill is, up to a certain point, a guide, it is far from being a safe one in all cases. Two rolls of exactly the same composition may have different depth of chill; and again, two rolls having the same depth of chill may differ very much in analysis. Although a user will not directly admit this if a roll breaks showing a perfect chill, the roll caster is told that the metal is too close, too high, too light in colour, and, as a sheet anchor, the good old standard complaint "That the iron has been burnt in the furnace" is let go at the unfortunate maker of the roll. I have never yet been able to get a proper definition of the latter. If it means that oxide of iron is present in the roll, consequently preventing perfect cohesion, I consider such supposition cannot be substantiated. In puddling, during the balling up, if the fire is thin and there is an oxidising flame or atmosphere in the furnace, doubtless some iron is burnt or oxidised and the burnt iron is incorporated with the ball; but in a furnace simply melting, the oxide of iron, being of a lower specific gravity than the charge or bath of metal, rises and forms slag. Again, it is well known that as long as silicon is present oxygen prefers it; manganese may be also said to protect the iron in the same way. Whether iron is first oxidised, and this oxide is afterwards reduced by silicon or manganese, is, for the moment of no consequence, the net result being that oxide of iron is, practically speaking, kept out of the casting if the iron is properly skimmed. Anyone desirous of further examining this will find much information in Major Cubillo's valuable paper which was read in November, 1893, before this Institute.

I am well aware that the question of breakage of rolls is a most delicate one, but it will not be cured by fighting shy of it, nor by trying to set the roll maker and the roll user at cross purposes, as some for want of better knowledge think desirable; it is to the benefit of both that rolls should not break, and if makers and users will meet each other on common ground, a great deal may be learnt that will be conducive to their mutual benefit. I frankly admit that bad rolls are made, and I must also say that the best possible rolls that can be made are broken, neither purposely, but more through the laws governing their manufacture and use not being thoroughly grasped by the actual workmen engaged in either operation; not that this is an easy matter, because the whole subject is a difficult one, and it is open to question whether

any single individual can say he has mastered the subject in its entirety.

I presume it will be admitted that cold rolls do not break so suddenly or apparently in such mysterious ways as hot rolls do; therefore, heat is the factor which lets loose the forces which have such immense power. When making large grain rolls it is customary to melt down old chilled rolls. A few minutes after these are charged into a hot furnace they invariably fly in pieces, sometimes in four or five or even more. Commonly the rupture is transverse, but it is not at all unusual for them to split up in a longitudinal direction; a sharp report is heard and you find two or more pieces instead of one. What is the cause of it? There is no mechanical strain at work, and when we consider that the tensional strain at only 8 tons per square inch to pull asunder, say a 24in. diameter roll, will be 24in. diameter  $\times$  452.3in.  $\times$  by 8 = 3618.4 tons, the force that is capable of doing such a tremendous amount of work must be great, and as heat is the only thing in the furnace likely to have any influence on the metal it may be well to consider its expansive action.

We can easily imagine that if the roll must expand on the side that the flame strikes, this side must be expanding at a greater rate than the other, which cannot absorb heat because it is not there. If one portion is travelling faster than the other, it is a physical impossibility for them both to occupy the same relative position to each other, consequently they part. In melting down old rolls it is of no moment; but when this gigantic force exerts itself upon new chilled rolls the result, although it may be a splendid example of the power of heat, is, from a financial point of view, anything but satisfactory. The actual operation in the case of a roll at work is slightly different to that of the old roll in the furnace. The roll at work will have the whole of the outside of the body at one temperature, due allowance of course being made for the extra radiation from the ends. At first sight it may appear that all is well.

Rolls break at most unaccountable times, not always at the actual time the strain responsible for the disaster has been put upon them, but, as I think most roll makers and users will agree, the time the majority of chilled rolls break is at three periods: When they are got up for work on Monday morning, when they are let down at the end of the week, and at night time.

I will endeavour to at least show some reason why rolls prefer the two first-named periods for self execution, but the latter one I am at a loss over. Will some user kindly help me?

When a roll is being got up for work, or in other words *thoroughly* heated to say 500°F. the heat must all pass through the outside; if the outer portion is heated at too quick a rate what is to be expected? The heated outside portion is travelling faster than the cooler central one, and it is futile to expect that they should hang together.

When rolls are being loosed down or cooled the reverse is the case; the outer portion is cooling and contracting at a greater rate than the central core, and if it is not done very slowly, rupture is the only result that can be anticipated. The outer skin is of a most brittle nature—to do its work properly it must be—and this outer portion is in tension, the heated centre being in compression, if the rate of cooling is too rapid, compression will soon get the upper hand, it is only reasonable to think so, and the outer skin is cracked. I know my friends in the mills will say "But they are loosed down slowly." Do they thoroughly grasp the amount of heat contained in a roll? I am afraid not. Get a coal fire, not too hot to be dangerous, and see how long it will take to thoroughly heat up a roll say 4ft. by 24in. diameter to 500°F. I have had at different times to heat up ends of grain rolls to burn on new wobblers, or sometimes a neck, and it has often been a great puzzle to me where the heat goes to.

Mr. Winder's diagram of a roll 3ft. 6in. by 24½in. diameter gives the temperature of body when work ceased at 500°F., 24 hours later this had only fallen to 100°F., or 400° in 24 hours. I am afraid as a general rule rolls are got up and down through 400° at a much faster rate. Hasty loosing down of rolls is, in my opinion, one of the most frequent causes of the failure of chilled rolls, and the roll only wants a little heat on re-starting to bring the whole matter to a head, in other words, to complete the fracture. We have been told that chilled rolls break before even passing iron through them. Now, rolls will not break if anyone looks at them savagely; if anyone thinks so I should advise them to try and break a roll, new or old, with a ball and legs. He will get tired of winding before he gets through with the breaking of the roll.

As a small practical illustration of what I mean, get a stick of sulphur about 6 or 8 inches long, let it be fairly cool, say 40 to 50°F., grasp it gently with the hand, which should be dry and as warm as can be made without discomfort. In a very short time the sulphur will give audible evidence of its fracture, and on examining it the surface will be found cracked, in most cases the stick will be completely broken in two or more pieces. To reverse the experiment, warm up very slowly a stick, taking care that it does not fracture; when it is about 90° or over place on a cold stone or in cold water, and you will nearly always find the stick fractured. The sulphur breaks because of the unequal expansion; it is such a bad conductor that the inside does not get sufficiently heated to enable it to travel as fast as the outside, or the reverse, according to which way the experiment is tried.

Boilers are frequently damped down from Saturday to Monday; regenerative furnaces, etc., are kept going to save a little fuel; why cannot rolls be kept warm, thus frequently save a valuable tool?

"Rolls frequently have their necks twisted off." That is the usual mode of expression, but is it correct? Unless there is an evident

defect we rarely, if ever, hear of a wobbler being twisted clean off. Then why should the point of fracture usually commence in the angle of the neck, where the neck is larger and should be stronger? If the heat of the body is being kept up, and even increased, is the neck allowed to become hotter or expand in the same ratio? We know that it is not so. Yet cast-iron is blamed because it cannot go two ways at the same time. Sometimes probably the neck does get too hot, but I am inclined to think that the failures in the necks of rolls arise principally from sudden cooling or from being kept too cool, and thus enormous strains are set up between the body and the neck. It is an awkward job to keep the necks at a right temperature, but would it not be better to do so than risk the destruction of the roll? To prevent brasses cutting let larger bearing surfaces, and if necessary larger housings be used. If we could only see before us the money value of rolls sacrificed because larger or longer necks could not be got in the housings of old trains, we should go home to-night sadder and wiser men.

Some rolls break because they are used too soon after their being cast; they are pulled out of the moulds too soon, and put to work too soon; that is because roll users will not order until they are compelled to, and sometimes even have their mills standing before the roll can come in from the foundry.

It cannot be too clearly understood that it is impossible to make such a casting as a chilled roll without internal strain, considering the different characteristics of its constituents. A few years ago I had occasion to put on the lathe and prove some rolls which had been cast as much as ten or twelve years ago, and which had never worked. I was very much struck by the fine grey appearance of the backs or the grey portion at the back of the chill, and I wondered why new rolls did not show the same.

It is well known in cold-blast furnace yards that high iron improves by keeping, and that iron which perhaps was stacked for, say, No. 6, some 10, 15, or even 20 years before ultimately finds its way into the market as a good No. 5 or even a No. 4. A short time ago an old roll turner of high repute told me, in conversation about the tendency of high cold-blast irons to become greyer with age, that in his early days a forge roll, which had been cast of cold-blast iron, on being put on the lathe, proved to be nearly white and too hard to turn; it was put on one side. Years afterwards the then manager of the works asked what the roll was. He was told that it had been put aside years before as being too high and hard. He decided to have it put on the lathe, and if bad it was to be sent to the furnace. It turned out then, although very high, too good to be condemned, it was turned, put to work, and did good service. I give this fact for what it is worth. My informant is alive and well and can, I feel sure, substantiate his statement.

I am not prepared to say that chilled rolls will become grain rolls with lapse of time, but it is more than probable that the continued expansion and contraction between day and night, hot and cold weather, has a tendency to ameliorate the original strain, and in all likelihood to cause some combined carbon to change to graphitic, and thus cause the roll to be tougher and greyer. The old system of keeping rolls in stock was, I am inclined to think, a better one than the practice now in vogue, though, whether it was done for a purpose, or the financial difficulty was then not so pressing, I am not prepared to say.

Rolls break because mills are undersized, or were never designed in the first place to do the work now placed upon them, housings are worn, chocks are loose and have to be lined or packed up. These are difficulties which are incident to all old plants; but it is to be regretted that proprietors do not, when putting down new trains, always realise the importance of having all housings, chocks, bed-plates, etc., truly planed and fitted. If one was to suggest that the engine was quite good enough if fitted together in the slipshod manner the mill usually is they would be horrified. Efficiency is sacrificed every day because the first cost looks alarming, but the extra first cost is a mere bagatelle to the subsequent failures and loss caused by cheap, rough fitting. Some of my critics will, no doubt, say that the fault of this lies with the builder of the mill; but it must be borne in mind that the builder is tied down to a certain sum. If purchasers will only pay the price, there are plenty of good engineers and ironfounders willing and ready to turn their work out a credit to themselves and their patrons, but their efforts must be recognised.

Continental firms, I regret to say, are certainly in advance of ourselves in this respect. Why should it be so?

Great stress (and rightly so) is laid upon the fact that at the present day rolls break more often than in former years, because they are harder worked. This, I consider, is properly a question of excessive heat, which I have already touched upon. If a roll could be kept (for rolls) at a comparatively low temperature and yet pass work through quickly, this trouble would doubtless disappear. We have had designs of rolls that we are told can be kept cool; but will any roller say they are practicable? From an ironfounder's point of view, I say they are not. Length of life in a roll should be properly measured by the class and amount of work done, not by time.

Bad turning is frequently debited with the cause of the failure of the roll. This, at any rate, is a thing which can be proved before the roll is put to work, and the blame, if any, laid upon the right shoulders. A roll turned week after week in the housings is not altogether the same thing. Necks wear, and should they wear oval as most journals do, the

body will be likewise, because it is simply an enlarged copy of the neck. When fracture is caused by this, it is not the roll's fault or its maker's either.

In connection with the breakage of chilled rolls, there is a point well worthy of consideration by some of our scientific members, that is, whether thermo-electric energy may not in some way have a strong influence upon the life of a roll. We see in various thermo-electric piles or batteries heat transposed into electric energy through the medium of good and bad conductors. In the roll we have similar constituents, but not in any order or system. The body of the roll is heated and the necks are cooled, the heat travels to the cool portion as well as it can, but it causes a strain or unequal balance.

Generally speaking, good heat conductors are good electrical conductors, and although it may appear far fetched at the moment, I believe that the roll of the future will not be a built-up roll, but one cast with good heat-conducting metals in its interior in such a form as will conduct heat from the outside to the inside, or the reverse, in the least possible time, and thus prevent unequal tension; but the practical difficulties in the foundry are very great.

Casting experimental chilled rolls is a very expensive amusement; therefore, improvement will come but slowly.

I quite believe that roll users are as anxious as makers to help to improve matters; therefore, let them consistently and regularly analyse the whole of their rolls for a good period, taking care that the drillings are always from the same position on the roll. The bottom neck or wobbler I would suggest. If taken from the interior of the roll or top end the drillings may contain a portion of the feed iron, and the analyses would lead to erroneous conclusions. Let them compare those that have done good work with those that have not. If there is anything wrong with the composition of the iron they will at least detect a difference in the analyses. Let them be more open with the roll makers. When they get an extra good roll give him its number or other distinctive feature, and say what it has done. I have no need to say anything about those that fail, as the makers are always informed about them, so in common fairness he should have the whole of the tale. At the varying temperatures of blast furnaces, etc., are now ascertained with the aid of the Roberts-Austen Thermo-couple, why should it not be possible to take those of a chilled roll? If a true diagram of the range of temperature for three months was taken I feel sure that it would reveal such unequal or varying lines, such sharp corners, that mill managers and proprietors would make at once every effort to keep their rolls at one mean temperature, from the moment they were put to work until they were worn out, with advantage to themselves both mentally and economically.

In conclusion, I cannot but feel that I have very feebly handled my subject. With a diagram of change of temperatures, the actual conductivity, rate of radiation, co-efficients of expansion, and tensional strengths being known, I believe it will ultimately be shown mathematically that rolls, as now worked, are subjected to strains which account for their collapse, and the result will be a more humane treatment of such a high strung tool as a chilled roll, and the saving of a great deal of loss and worry to the maker and user. If my humble comments will assist in reaching this desirable end it will ensure me much gratification.

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## THE DISCUSSION.

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THE PRESIDENT: We have had a very instructive paper this evening from Mr. Nicholson, and I hope we shall have a few comments upon it. One question I might mention is the heating up of chilled rolls. Some years ago we used to heat the rolls before using them, by means of a gas jet, so as to get them up to a fair temperature before using them, keeping the rolls turning the whole time. I feel certain that was very successful, and saved many rolls from breaking; but I hardly think it was necessary to keep the gas on the whole of the time like we did. After the works had stopped on Saturday we kept the gas jet burning, so that the rolls did not get down to a low temperature; therefore we did not get unequal contraction and expansion to any great extent, and breakages were consequently partially avoided. I expect not many here have had any experience with rolls, except those of Staffordshire make. I have had a little experience with rolls made in another district, so I have brought a few figures showing the life of Staffordshire rolls compared with those from other districts. The rolls in question were 36in. hard plate rolls. I will give you, first of all, those made in Staffordshire. The first worked 12 days of 24 hours and then broke. All the "days" are 24 hours in these figures. The second was turned twelve times, and it worked 320 days and was not broken up to the time I last heard of it. The third was turned fourteen times and lasted 428½ days, and was in the mill when the record was taken. The fourth was put in twelve times and ran 318 days when it broke. The fifth ran 293 days without breaking, the 6th 177, the 7th 92 days, the 8th went 17½ days and had then not been broken, and the 9th 20½ days and had not broken. Now we come to those from another district. The total life of the first was 43 days, 2nd 8½, 3rd 45 days, 4th 1 day, 5th 28½ days, 6th 186 days, and that was a good roll and is still working, the 8th worked one day, the 9th 8½ days, the 10th 89 days and is still working, the 11th 21½ days, the 12th 4 days, the 13th 42 days, but it had its shell worn off after being turned twice; the 14th 9½ days, the 15th half a day only. Those

were NOT Staffordshire rolls. I was at a works in another part of the Kingdom then, and I never could understand why we should continue to use a much larger number of these non-Staffordshire rolls when the Staffordshire rolls did much better; but I was simply works' manager and had no control in the buying of the rolls, otherwise I should have come to Staffordshire. A good plan, which is carried out in many works, is that when finishing work on Saturday afternoon the chilled rolls are covered up, so as to keep them warm and not let the rolls get cold. It is a great help to the rolls and is very little trouble; it helps the rolls to have a longer life, and I think it is a point worthy of consideration.

MR. H. SILVESTER: A friend of mine, who does not possess a very extensive acquaintance with the technical terms of the iron trade, upon hearing the title of this paper, asked what chilled rolls were. I said, "It is very paradoxical; but chilled rolls are articles which produce "warm discussions, at any rate when they are of an ideal character." To-night Mr. Nicholson has dealt chiefly with the every-day chilled roll, only touching incidentally on the ideal roll. There is no manufacture that appeals to, and more widely interests, members of this Institute, than the production of chilled rolls. Blast furnace manager, founder and sheet maker are all keenly concerned, and have very strong and diverse views as to the character and quality of the iron, and the causes of failure. The pig maker is on his mettle at once, if there is a suggestion, which founders have been known to make, that the quality and regularity of the cold blast iron of to-day is inferior to that of, say, 20 or 30 years ago, whilst the sheet maker is apt to cry, a plague on both blast furnace and foundry because the chilled rolls of to-day, though turning out a much heavier tonnage, do not work the same length of time as when a smaller daily output was the custom in the mills.

On page 51, Mr. Nicholson gives a table of the different physical characteristics of the constituents of a chilled roll, and appears to point to the diversity in melting point and specific gravity of the elementary constituents as the cause of the difficulties in making reliable rolls. But these substances—carbon, phosphorus, sulphur, etc.—are more or less chemically combined with the iron, and the properties of the resulting compounds are entirely different from the elementary substances composing them, and no importance can be attached to such figures.

On page 53, the author gives an average analysis of a No. 5 Staffordshire cold-blast iron, in which he puts graphitic carbon at 2.443%, combined carbon .538%; total carbon 2.98 per cent. But my experience would lead me to put the total carbon in an average of Staffordshire cold blast pigs at 3.3 to 3.4 per cent. I have looked up a considerable number of analyses, and find the total carbon varies from 3.25 to 3.5 per cent. This point is important, because we have not yet got to the bottom of the value of high total carbon in castings. It is generally admitted that a good chilled roll should have a grey "back,"

that is the ratio of graphitic to combined carbon should be high, and with the other constituents suitably present, this is more likely to occur with a total high carbon. Lower down, Mr. Nicholson draws attention to some analyses of old and modern cold-blast irons, which I gave in connection with a previous paper on this subject, and suggests that the modern iron is not so good, owing to a slight increase in the percentage of the sulphur—.08 to .1 per cent. But .1 per cent. is not excessive for roll purposes, and with the lower amount there would be a probability of a too mild chill and soft face. Cold blast iron, in common with every other constructional material, is more severely tested to-day than ever it was, and as a consequence the maker is compelled to turn out a pig of fairly uniform composition which, I believe, will compare favourably in every respect with the product of the past.

On page 54, the author quotes the analysis of the proposed ideal roll, but does not at all agree with the suggested composition, and I am afraid its ideal character would soon be broken if ever it found its way into the mill. With the exception that the phosphorus is low, the analysis is that of a basic pig iron, which has a dense spiegel-like fracture; and this, it appears to me, would be the character of the chill of a roll made from an iron of the composition given, and one would expect spawling to take place. As regards the meaning of "burnt iron," it is a loose term I have always heard used to describe a roll giving a high fracture—that is, a comparatively low percentage of graphitic associated with a comparatively high percentage of combined carbon. The iron is certainly not burnt in the sense that oxide of iron is present; but the light close fracture may be due to a too prolonged exposure of the iron to a more or less oxidising flame, whereby the total carbon is reduced, and also the silicon. Excessive sulphur gives the same fracture, and the roll is then frequently said to be cast of "burnt iron." With reference to the taking of drillings from a roll, the author urges that they should be taken from the bottom neck, otherwise you may get some of the feed iron in your sample. But may not this feed iron be the cause sometimes of failure, and the taking of drillings from a spot where it cannot possibly occur thus lose a chance of explaining a possible course of breakage? Mr. Nicholson has given us a most interesting paper, and one that cannot help but be of value to all who are interested in the manufacture and use of chilled rolls.

MR. A. E. TUCKER: I associate myself with Mr. Silvester's opinion that this paper has been a most valuable one, and I am sorry we have not had it in our hands before. It certainly opens an excellent field for our discussion, and I must begin by assuming the attitude more of a learner than as offering any opinion. It occurs to me to enquire, why should mill managers consider it necessary to raise the heat of the rolls to as much as 500 degrees Fahrenheit—that is about 260 degrees centigrade—before starting the rolling of sheets. Chatelier, in the *Proceedings of Civil Engineers*, 1893, gives some results bearing on

the question of the elastic limits of cast-iron. He says the elastic limit increases very considerably with an increase of temperature between  $100^{\circ}$  centigrade and  $350^{\circ}$  centigrade; but that after  $350^{\circ}$  it decreased very rapidly, and after passing  $400^{\circ}$  or  $450^{\circ}$  it was no longer possible to estimate any elastic limit at all. So you see in a mechanical structure such as a chilled roll where you have practically different constituents in the interior to what you have in the outside, the raising of the roll to  $500^{\circ}$  Fahr., must submit all the structure to intense strains, and I should like some information as to why you should raise it to that temperature at all. I would suggest that every opportunity should be taken to keep the roll cool, rather than to maintain it at an elevated temperature. Mr. Silvester has very properly criticised the remarks on page 51, with regard to the properties of constituents of a roll, and he has pointed out that Mr. Nicholson has gone a little astray in assuming that the elements of which he gives details, set up great strains in cast-iron, by reason of their diversity of characteristics. As a matter of fact, these elements do not exist as such in the roll, but as compounds having very different properties to their elements. On p. 52 the author deals with the question of manganese in chilled rolls. That opens up a very interesting point, and I have had a great deal of experience upon it; he also alludes to it again on p. 54. It is a very curious thing that, not only with steel but also with cast-iron, the addition of small quantities of manganese very considerably alters the character of the metal in a manner different from what might have been expected. The structure, also, alters immensely, and had the percentage of manganese been increased to 1.5 instead of .56 (see p. 55), as Mr. Nicholson wished it to be, I have no doubt at all that the structure of the roll would be essentially different to what he gives. In one case I recommended the addition of ferro-manganese where an extra hard surface was desired, but the effect of the small addition, which was intended to give altogether 1.5 per cent., made the surface quite soft, instead of, as was expected, making it hard. Having been associated practically with works, I have been greatly struck at the very absurd size of the brasses which are sometimes used in the housings of rolls. You often get a surface going over  $\frac{1}{4}$ th or  $\frac{1}{2}$ th of the periphery of the neck. Now, in a decently constructed machine, the neck or journal is practically entirely surrounded with the brass or the supporting metals. Why should not that obtain in rolls? The effect of limiting brasses to such a small size involves a possibility which very seriously determines the life of a roll. If you take two cylinders, and have their axes in the same vertical plane, the line of contact will be continuous from one end of the roll to the other. But if, from a shifting of those two axes from the vertical plane, you get a crossing of those two axes, then instead of the line of contact being continuous along the rolls, the contact occurs really only at one point. Therefore, the admission of any material between the rolls must set up an enormous strain at that one point, which, I take it, the roll is frequently unable to stand, whether cold or hot. It therefore

follows that the rolls very often break from the weakest mechanical point with regard to area, namely, the neck ; or if these are balanced, the roll will break in the middle. I cannot see why a simple mechanical arrangement could not be arranged, in order to at once determine whether the two rolls were or were not in the same plane. On page 61 Mr. Nicholson alludes to the proposed use of the thermo-couple. That is now a perfectly practical instrument for foundry work. The pyrometer which I understand we shall have described to us soon is so perfect and simple that an intelligent workman can absolutely determine the temperature. It can easily be used with molten iron, and is, therefore, of immense assistance in securing uniformity of temperature during roll-casting. There is no particular reason why the Roberts-Austen pattern should be used, as that is really only an ordinary Chatelier pyrometer, coupled with an elaborate arrangement of clock, &c., which is not necessary for the purpose I am alluding to. I again thank Mr. Nicholson for his excellent paper.

Mr. J. W. HALL: I propose to confine my remarks this evening to one paragraph on the last page of Mr. Nicholson's paper, wherein he says, "I believe it will ultimately be shown mathematically that rolls, as now worked, are subjected to strains which account for their collapse." Now I have been daring enough to attempt to calculate what degree of heat, applied to the outside of a roll, will set up such strains in the mass as must result in the fracture of the roll, although it is subjected to no strains of any other kind whatever. When heat is thus applied, the outer surface of the roll expands longitudinally, dragging with it the cold central portion, whose resistance to extension holds back the outside from expanding freely, thus putting the outer skin in a state of compression. A compromise is effected, the actual amount to which the roll is lengthened by the heat depending upon the relative areas of the hotter and colder portions, until the outer portion being compressed, or the inner extended beyond its power of resistance, rupture occurs. Now there are data available (the records of numerous experiments), from which we know the following facts:—(1) Cast-iron lengthens under tension and shortens under compression, to the extent, in round figures, of  $\frac{1}{10,000}$  parts of its length for each ton of force exerted on it. (2) Conversely, when cast-iron is extended or compressed  $\frac{1}{10,000}$ , we know this is the result of a force exerting a stress of one ton per square inch, and so on proportionately up to the point of fracture. (3) The ultimate power of cast-iron to resist compression, is, on an average,  $3\frac{1}{2}$  times as great as its power to resist tension, and consequently the maximum ability to resist fracture is secured when the portion of the section under tension is  $3\frac{1}{2}$  times as great as the portion under compression, both portions thus taking their fair share of the work (the maximum which each is capable of sustaining), so that fracture is not caused by one part yielding before the other is fully loaded. (4) We may take the ultimate strength of the best cast-iron used for rolls at 10 tons per square inch in

tension, and 35 tons in compression. (5) Obviously then, if any force extends a portion of the roll,  $10 \times \frac{1}{10.000} = \frac{1}{10.000}$  of its length, or compresses it,  $35 \times \frac{1}{10.000} = \frac{7}{2000}$  of its length, in each case the ultimate strength of the material is reached, and fracture results. (6) We also know that cast-iron extends  $\frac{1}{10.000}$  parts of its length for each  $100^\circ\text{F}$ . rise in temperature. Now take a roll at atmospheric temperature, say for example, the 24in. roll mentioned by Mr. Nicholson, which has a cross-sectional area of 452 square inches, and heat the outer portion to the extent of 100 square inches of cross-sectional area so rapidly that the inner portion of 352 square inches area (answering to a diameter of 21 inches) remains unheated. To what temperature must the outer shell  $1\frac{1}{2}$  inches thick have been raised when this outer portion has by its expansion extended the inner portion  $\frac{1}{10.000}$  (which is the breaking point of the inside), and at the same time be itself held back by this resistance of the inner core from expanding  $\frac{7}{2000}$ , the point at which the outer shell would fail by crushing? Evidently that degree of heat which would have extended the outer skin  $\frac{1}{10.000}$  had meantime been at liberty to expand freely, and that is  $\frac{100 \text{ by } 100}{6} = 1500^\circ\text{F}$ . rise of temperature. With the roll originally at a temperature of  $50^\circ\text{Fahr}$ ., this means that the roll must fly in pieces when the outer skin to a depth of  $1\frac{1}{2}$  inches inwards has been raised to a temperature of  $1550^\circ\text{F}$ ., if the centre still remains as cold as at first. At  $1550^\circ\text{F}$ . the roll will show a low cherry red colour. Of course a lower temperature penetrating to a greater depth than  $1\frac{1}{2}$  inches will cause fracture of the inside before the outside is at its breaking point, and the conditions I have taken show the *maximum* variation in temperature possible, between an outer zone and an inner core, without fracture of one or the other. But for the fact that the great conductivity of iron, and its high specific heat, render it difficult, as pointed out by Mr. Nicholson, to heat one portion of a roll to a temperature ver. much exceeding the colder portions which are rapidly robbing the hot portion of the heat supplied to it, it would be impossible to use any rolls, much less chilled rolls, for working hot material at all; and the further fact, pointed out by Mr. Nicholson, that when subjected to high temperatures applied suddenly externally, as for instance when a roll is dragged cold into a very hot furnace, the roll flies in pieces directly, proves the existence of strains of a magnitude such as calculation shows must inevitably be set up. When we remember that the surfaces of chilled rolls are already in a state of compression, and the centres in tension, owing to the initial stresses set up internally by the process of chilling, which forces there is no possibility of calculating, to say nothing of the weakening effects of heat, the wonder is not that such rolls sometimes fail, but that they ever stand at all, as the margin of safety, when heated, must be exceedingly low.

Mr. MOSES MILLARD: Why is it that we have had epidemics of roll breaking? A few years ago, everybody was breaking rolls. There was hardly a man in the trade but what was crying out, "Oh, the rolls I am

breaking! It will drive me mad." To-day we are comparatively free from this, and it is a good thing, because sheets are almost being given away. I should like to advise Mr. Nicholson not to place too much reliance upon analyses. They are not always to be relied upon. If we also make an examination by means of the microscope, as explained to us here on one occasion by Mr. Stead, then by means of an ordinary chemical analysis, and that examination combined, he will be going in the right direction. The author, on p. 54, quotes a case in which ferromanganese actually made the roll softer instead of harder, and he gives an analysis of the metal before and after adding the manganese. I should like to know whether that was a large piece or small?—[Mr. NICHOLSON: A test bar.] The author makes rather a strong stand at users taking the makers by the ear and pulling them about, simply because the roll users meet with breakages at times. In another place he advises roll makers and roll users to work together. I have advocated that more than once. I have entreated the roll makers to meet together in conference, and see if they cannot find out something. That was at a time when as fast as rolls were being put in they were being broken. Then came this lull, and I am afraid the makers, after having manifested a good deal of care in selection, have now gone to sleep; and, because so many rolls are not being broken as formerly, the ironmasters have done the same. But I tell you, we are just on the margin of another epidemic. Yes, as sure as to-day is the 11th of February, we are on the margin of another epidemic of roll-breaking—save and except Mr. Nicholson and his compeers tell us how to avoid it. On p. 57 he says rolls break at most unaccountable times. That is quite true. He then goes on to say that the time the majority of chilled rolls break is at three periods, namely, when they are got up for work on Monday morning, when they are let down at the end of the week, and at night time. Well now, we work ours night and day, and for one we have broken in getting up or letting down, we have broken forty whilst at work, so I think Mr. Nicholson is wrong on that point. I admit, however, that a too sudden getting up of the temperature will break them. In fact, I will undertake to break any roll for you if you will let me have it cold to start with. As to the neck being kept at one temperature, Mr. Nicholson must forgive me if I say with respect to that point, that it is evident whatever he may be as a maker he does not understand the using of rolls, because if he did he would know that there are times when we must have the necks hot and times when we must have them cold. If you could keep them at one regular temperature it would be a good thing, but the exigencies of the trade won't allow you to do it, and therefore the rolls have to be made to meet variations of temperature. The author speaks about new rolls breaking quicker than old ones, but I scarcely think that can be relied on. However, on the whole, I think the paper is a good one from the roll makers' point of view. I would advise Mr. Nicholson to induce his friends, including himself, to get together three, or four, or

half a dozen, good roll makers, and about the same number of sheet-roll users and experienced men. Let them get together and each one give his own experience, and I believe good would result. This is on the whole a good paper, and when the customary vote of thanks is proposed to Mr. Nicholson, there will be no more hearty supporter than myself.

MR. H. PILKINGTON: I am sure this paper has had a very much better reception than the last paper read here upon chilled rolls had. I agree with a great deal that has fallen from the lips of Mr. Millard about the question of meeting together and talking about rolls. There has been a good deal of unnecessary reticence hitherto. Every roll maker has been considered to possess some very profound secret which enables him to produce extra good rolls; but I think many of these so-called secrets are unknown even to the roll makers themselves. At the same time, the more the question is thrashed out from the roll makers' point of view, the more we are likely to attain to a decent roll. Investigations have been going on in recent years which have led to very rigid requirements being placed upon the makers of cold blast pig iron. It is an absolute fact that cold blast pig iron as a rule must of necessity be very much more regular and better in quality than was the case a few years ago. In former years a great deal of cold blast pig iron went into rolls which was not of a proper character. The proper investigations and analyses were never undertaken, and any roll failures were not followed up by inquiry into their causes, and by the ascertainment of proper remedies. Now with regard to the analyses of cold blast iron given in this paper, I happen to have in my possession the average analysis of about half a dozen rolls which did exceedingly good service. It is—silicon, 1.21%; sulphur, .11%; phosphorus, .46%; and manganese, .29%; but the graphitic carbon is 3.42%, and the combined carbon is .3%. It seems to me there is a great deal more in the carbon contents of chilled rolls than we commonly suppose. I don't propose to say anything about the various kinds of carbon, we know but little about it, and in fact the "doctors" themselves don't agree about it. But I think, perhaps, the analyses which I have in my possession of other things than rolls have gone to prove that the accepted theories as to carbon in cold blast and other pig irons are not always correct, and that more investigation is necessary before anything definite can be pronounced. I myself got some facts together and intended to go into the matter along with Mr. Silvester a little time ago, but other things intervened; but I hope to do this at a future day. There is another point in the paper exceedingly interesting to me, and that is the undoubted fact that the addition of a small percentage of manganese will make the iron greyer, and therefore reduce the depth of chill under certain conditions. That is proved very readily by certain brands of ordinary foundry pig iron. In some districts the furnaces make an exceedingly small percentage of foundry iron, where the manganese is under  $\frac{1}{2}$  per cent. When that manganese is increased to 1 per cent., the percentage of grey iron

increases marvellously. That of course goes to confirm the statement about the use of manganese, so far as concerns reducing the chill under those conditions and making the body of the roll greyer. I think that comprehends practically the whole of what I have to say upon the subject. In the last few years I have myself had to come into contact with rolls not made in Staffordshire, and I have had very convincing experience that Staffordshire is the proper place to come to for rolls.

Mr. H. B. Toy : The first part of the author's paper which I should like to criticise is that relating to the amount of machining necessary in rolling mills. For cold rolling mills it is quite essential to properly machine all parts to insure a good fit ; but for hot rolling mills, whilst admitting the importance of planing the feet of housings, bed-plate, recess for bottom brasses, boring eye to receive pin and box ; it would, in fact, be a mistake to plane loose chocks, &c., as the expansion by heat renders it a very difficult matter for the rollers to change the rolls, and if clearance be necessary it should be allowed for in the castings, as they will wear much longer than when the hard skin has been removed by planing.

Mr. Tucker's remark as to the contact of rolls in a sheet mill is a very important one, for in my opinion many breakages of chilled rolls are the result of neglect in this detail, and knowing that the top roll is adjusted with liners at the back of the top side brasses, I think all practical men will agree that there is room for improvement in the method at present adopted.

With regard to cold blast iron, I quite agree with remarks previously made, and may state, as far as chemical and practical tests are concerned, that makers are supplying a quality at the present time, equal to that made many years ago, but whether the ironfounder has more trouble in selecting the pigs is a question.

Mention has been made about epidemics in breakage of chilled rolls, but although I am bound to admit that bad rolls are made, I cannot agree with the complaint usually made that a roll is bad because it has broken, and in these epidemics the employment of trained engineers in iron and steel works, competent to adjust rolls and machinery, would, I am sure, obviate to some extent this trouble.

I think most managers of sheet mills will agree that it is unequal expansion and contraction which breaks the majority of sheet and plate rolls. I have seen myself attempts to expand the centre of sheet rolls to complete an order of a particular gauge of sheet, by running water on the necks ; and although this and many other details have to be resorted to, they will ever remain causes for breakages.

I have seen experiments made to prove that chilled rolls work safely if the heat be absorbed uniformly ; and in one case 480 tons of plates were produced through the one pair of chilled rolls in 24 hours, without

breakage. And I have particulars of a pair of Staffordshire chilled plate rolls, used for most suitable orders, in a mill producing over 1,000 tons of  $\frac{3}{4}$  in. plates per week, and altogether 7,500 tons of plates passed between these rolls, this result being obtained before the use of water upon the rolls was the custom.

Mr. J. M. LLOYD: The question which occurs to me is, how are we going to turn rolls? In summer time they are hardly cool enough on Monday morning, after they have stood all the week end. Roll turners can pretty well tell what sort of a roll they have by examining the neck. When I have had a roll which was too hard, I have often felt sorry I had got to go to the trouble of turning it, because I knew it would not last long. We ought to anneal our hard rolls. I have known this done in a small way, and I believe we could get out of a lot of trouble by adopting some annealing process. As to rolls getting across and causing strain, the manager is a poor one who cannot tell, as he walks through the works, whether a roll is in line or not, and if not, he can soon have it altered. If he sees it  $\frac{1}{16}$ th of an inch out, he can go to the back and put a little liner in. But they do get across sometimes, and that is the cause of many breakages. I think we should be better off if we had longer and larger necks. The best system I have ever known has been drilling holes upon the end of the roll, as was done at Chillington in 1866 or 1867, to try to bring down the middle of the roll at the same rate as the outside. My experience is that breakages are caused in most cases by unequal contraction and expansion between the outside and the in.

Mr. Jos. COLLEY: In working the rolls, we often find that the bottom neck is the best, and that the top neck gives a great deal of trouble owing to the honeycombing, and then we have trouble with the brasses cutting. It seems to me they are not sufficiently fed, or the head of the roll is not long enough. I have heard of cases in which good results have been obtained by casting the rolls hollow instead of casting them solid, and then letting the inside cool simultaneously with the outside. I have known cases where cold blast irons have stood a strain of five tons per square inch, but after a series of re-meltings they stood as much as 12, and even 15 tons to the square inch. In the foundry, when a great deal of work has to be done, continuous fusion has to be provided for, and iron should be kept liquid three hours before tapping. In cases where the iron is re-melted many times, this continuance of melting had a good effect upon the strength of the metal up to twelve times, after which it deteriorated, and that bears out the point referred to as to the testing. You would require to have a pyrometer to keep the heat uniform. There are so many things to consider that roll makers and roll users hardly know what is the best thing to do; rolls break, and then we take a chemical analysis in order to find out. There remains a great deal more to be done in the foundry before we can be said to know all about casting. The greatest care should be taken in casting to have

the metal perfectly liquid, and of the right temperature; to give time in cooling, and to assist the natural process of crystallisation, so as to allow the crystals to form regularly, in order to ensure uniformity of tension in all parts; then I think, with good iron to begin with, we may ensure good rolls.

Mr. A. R. BANKS: When we were in the sheet trade we used sometimes to have rolls which worked for three years without breaking. On one occasion we had a man who got through a tremendous lot of work with a pair of rolls, but it snapped them entirely. Perhaps that was a case of unequal expansion owing to the hard driving.

Mr. L. D. THOMAS: We have had excellent testimony both from roll users and roll makers. Yet after all that has been said there is plenty of room for another night's discussion. The paper is a good one, although it contains a lot of egotism, by which I mean that it is all Staffordshire. But I think we have, at any rate, had the solution of the epidemic problem mentioned by one speaker. At the discussion on the last paper on this subject, two or three of the roll makers blamed the blast furnace managers. They said they could not get a good pig. Now I admit that there has been carelessness in the past, but according to Mr. Pilkington, better pig iron is produced to-day than before, and that may explain the disappearance of the epidemic. With reference to trouble being experienced from shelling, I know that on the Continent, between the heats they throw cold water on the rolls. I was speaking to a gentleman this week who has seen that done continually, and that may be the cause of the shelling. As to the quality of the rolls made to-day, I don't believe better rolls were ever made, because they were not required a few years ago to stand the wear and tear that is put on rolls to-day. In former times rolls were smaller than they are now, and they were used for rolling iron and for rolling it hot. To-day it is nearly all steel that has to be rolled, and you must roll it as cold as you can, in fact, black if possible. From that point of view I congratulate the roll makers, for they have made rolls which will meet the altered conditions. Occasionally mishaps occur through the carelessness of the roll turner; but as to the rolls being out of line, that state of affairs would not last for long in a properly conducted mill. Difference in the quality of the material rolled often accounts for difficulties. Some pieces of steel bars are soft and roll like lead, and the next piece may be "as hard as an old man's head." The same piece may also vary in different parts of it. With regard to some of the figures mentioned during the discussion, I notice that thirteen tons of steel bars were rolled through one pair of rolls in twelve hours, so they must have been very good rolls. I congratulate Mr. Nicholson upon his paper.

Mr. E. D. NICHOLSON: With regard to our President's remarks, I don't think they call for any comment from me, I am proud to think that the Staffordshire rolls give such good results. I may say, before I

go any further, perhaps, that some of those present do not quite recognise the position in which I stand. I wrote this paper four years ago at the request of your Secretary. Since then, I have had, fortunately or unfortunately, little or nothing to do with the roll trade. I was unable to give the paper before, but being again asked, I give it now. I don't hold a brief for the maker; I don't think, indeed, that I have overstated the case on either side. I want to be perfectly fair in the matter. We all need to pull together—both makers and users. Mr. Silvester has remarked that I have lost sight of the fact that when the iron is melted some of the chemical elements are combined. My figures at that point are quoted from Daniel Adamson's address before the Iron and Steel Institute, in 1877, so they ought to be correct. I used them not so much to show the particular action of individual elements, as to show what a number of different elements had to be considered and dealt with. With regard to the total carbon, Mr. Silvester says he prefers it  $3\frac{1}{4}$  to 3.5, and I am rather inclined to agree with him. The average analysis I gave is taken from scores of pig over two or three years. You can get one analysis and make anything you like of it; but if you are to get a general result you must obtain an average. I have simply given what they came out at in the average. Mr. Silvester also recommends a little more sulphur. My experience is that if you want sulphur you can always put it there, but if you have too much in, it is hard to get out. Personally, therefore, I prefer to have a low sulphur to start with. As to drillings. Why I should like these from the bottom neck is that if you get it from the interior of the roll or top end, the drillings may contain a portion of the feed iron, which is generally a hot-blast iron. If that is mixed with your cold blast iron it is not going to give you any knowledge of the composition of your roll. I don't see how it can.—[Mr. SILVESTER: But it explains how it breaks.]—Mr. NICHOLSON (continuing): Well, you must feed it, and I never heard of a roll being fed with cold-blast iron. Some remarks about the temperature of the rolls were made by Mr. Tucker. He did not see why it was necessary for them to be up to 500 degrees. Well, I took that temperature from a paper which was read here some time ago. The other questions raised by that gentleman have, I think, been answered by different members in the room. Mr. Hall has been good enough to go into the mathematical side of the question, and I think he has very ably put it before us. There is no doubt that when we get the rolls hotter and hotter, the tensional and other strains are very much increased. Mr. Millard speaks about an epidemic of roll-breaking. I think he answers himself when he says that sometimes people get careless in handling rolls. At the same time, his suggestion as to all meeting together to get, perhaps, at some common meeting ground whereby information could be obtained which might generally assist all parties, is a very good suggestion. On all such questions, what we want is information—"more light," and the more light there is, the better. The fact is, there are really no very

great secrets in roll making. It is right down hard, careful, persistent work which will make a good roll. You have to keep your nose to the grindstone if you want to make good rolls. As to the test bar. It was 1½ in. deep, 8 in. or 9 in. long, and 8 in. wide. As to breaking rolls at night, my experience is that all rolls frequently break at night. We are told so at any rate. The men said so. The question of making the necks hot or cold has been very well answered by Mr. Toy. It is really a question of altering the temperatures up or down. Now, Mr. Millard says he does not believe new rolls will break any more than others; but I think new rolls are much more tender. Take a hot roll out into a cold wind and you will very soon see the effect of sudden changes of temperature. In *The Engineer*, of February 3rd, 1899, there is a table given of some interest. *The Engineer* states that in the discussion of a paper on "Specifications for Structural Steel and Rails," read before the Franklin Institute some time previously, Mr. A. R. Stevenson, of the Standard Steel Company, Burnham, Pa., gave some results of tests, showing that the strength of railway tyre steel is increased by allowing a few days' time to elapse between the time the product is finished and the tests are made. The figures show that when the testing took place, seven or ten days after the tyre was made, you get 10,000 or 12,000 lbs. more ultimate strength. Now, if better results can be got from railway tyre steel, three, five, or seven days after it has been produced, surely chilled rolls ought to give better results a little later on than they do immediately on being cast. There is no doubt the initial strain has a lot to do with it. If you are making some very hard rolls for paper work, they sometimes jump right in two of themselves; it is simply the initial strain. They want time to get used to the work. As to quality, I don't think roll founders often put iron in wrongly if they can help it; nor do I think there is so much inattention either by founders or users, as some of the speakers seem to think. There may have been carelessness on both sides in the past; but I think that more attention has been called to the question both of making and using, of late years, and the very fact of having discussions on the matter, makes men think, and by thinking, the makers and users all take more care than otherwise. I think the manganese question answers itself. Manganese is really not reliable—you cannot depend upon it. With reference to brasses, there are sheet mills, or were, in which more than sufficient room for expansion was left. You could put your finger into some. I think that point is almost immaterial. At any rate, it won't do to make the brasses too large. You don't want the thing to be moving about, so to speak. If you can get, by good casting, a fairly decent fit, all well and good; but I have had a great deal of experience with cast-iron, and I know that if you want a good job, there is nothing like machining it. I think myself, it would be better to have the bearings all machined. If there is too much expansion in the brasses, there is pretty sure to be disarrangement of the working parts. Mr. Lloyd shows how desirable a uniform heat is; but

other speakers ask how we are to keep it uniform. Of course, if it is the variation in temperature during use that does the harm, then you cannot blame the roll-maker. You must blame the user. This question of temperature is an exceedingly difficult question altogether. I am glad that some of the speakers concur that larger and longer necks would be better. I believe that with small necks there is a crimping kind of action. Some necks will come out of the roll. The body wants to expand and the neck wants to contract, and they must part. One speaker finds the bottom neck best ; that is so. Holes in the top of the neck may come from iron that has gone a little cold. With regard to the feeding. If you get too long a head, bigger than the wobbler, you would find the top of the head would close up in the interior before you get the rest of the roll solidified. It is difficult sometimes to keep the top of the head open so as to get fluid iron into the interior ; but if you don't do this, you get cavities in the interior of the roll. One speaker "pitches into me" about egotism, but I don't think it is egotism to say that Staffordshire makes the best roll when it does. Egotism is bounce, but that is not bounce. There have been papers read here before, in which assertions as to the superiority of the Midland rolls have been made, and they have never been challenged by outsiders. As to cooling, I think if cold water was put on, there is not the slightest doubt i would spawl. I am very proud to hear some of the speakers admit that as good rolls are made to-day as ever. But we want to keep on doing better and better. As regards the rolling of iron and of steel there is no doubt it will be unequal. We must all do our best.

A vote of thanks to Mr. Nicholson, moved by Mr. SILVESTER, and seconded by Mr. HALL, was carried unanimously.

The fourth Meeting of the Session was held at The Institute. Dudley, on Saturday, the 11th of March, 1899.

THE PRESIDENT (Mr. H. LE NEVE FOSTER) occupied the chair.

The minutes of the previous meeting were read, adopted, and signed.

Mr. THOS. H. WALLER then read the following paper :—

## THE MEASUREMENT OF HIGH TEMPERATURES.

By THOMAS H. WALLER.

In many operations in the industrial field a knowledge of the temperature to which substances must be submitted for the purpose of bringing their mutual affinities into play, or of the temperature beyond which they must not be heated if we would avoid reactions which are not desired, or, again, of the temperature of the gases which pass either into or out of our furnaces, is of such obvious importance to the proper regulation of these operations that it almost needs an apology on my part for reminding you of it.

On the other hand, when we once get to the region of temperatures higher than the boiling point of mercury the difficulties of the determination of temperature rapidly increase. A little step beyond is gained by filling the tube of the thermometer with some inactive gas, such as nitrogen, so that the increase of gaseous pressure as the mercury is pushed along the tube may raise the boiling point of the metal. Again, Baly and Chorley's thermometer, which is filled with the liquid alloy of potassium and sodium, is available for some little way higher. A point, however, is pretty soon reached at which the glass of the bulb and tube softens and melts, and though some of the Jena glasses made by the celebrated firm of Schott are remarkably refractory, a very dull red heat is practically the limit of the use of thermometers of the ordinary construction, using the alloy of potassium and sodium, just mentioned. Although this is quite sufficient for many purposes, such as the determination of the temperature of flues, or of a blast furnace blast, such instruments are fragile and awkward to read—at any rate as to flues, which, by the very nature of the case, are frequently in places which are very inconvenient to get near enough to read a fine thermometer.

The expansion of a gas may also be used for purposes of thermometry, and if the envelope is made of glazed porcelain the instrument is available up to very high degrees of temperature. Barus found that if the bulb was glazed on the outside, and the pressure of the gas at the high temperature became high, a certain error was produced by the blowing out in bubbles of the melted glaze. Hence he was careful in the very important series of experiments which he carried out for the comparison of some of the methods of which we have to speak later on, to begin with such a low pressure of gas that even when the heat was at the highest point, and therefore the pressure also was the greatest, it should be less than that of the atmosphere, so that the tendency should be for the viscid glaze to be pressed into the pores of the porcelain, and this

plainly could only take place to such a very minute extent as to be quite negligible.

For ordinary use in furnaces, &c., the air thermometer can scarcely be considered of practical importance. It is cumbersome and needs fine and delicate apparatus to read its indications, and such are generally quite out of place in the situations where determinations of high temperatures are required. The main interest attached to the air thermometer is the way in which its indications lead to the idea of an absolute zero of temperature. If we enclose a volume of air, or preferably hydrogen since the law of expansion is in this case simpler, in a bulb, and determine the change of volume for each degree change of temperature when the pressure is kept constant, or on the other hand, the change of pressure per degree when the volume is kept the same, we shall find that the decrease for each degree of fall of temperature is a constant quantity, and is of such a magnitude that if the cooling could be continued to  $273^{\circ}\text{C.}$  below the melting point of ice, the volume (or pressure) would become zero. We know that before any gas was cooled to that extent the rate of change would diminish, indeed even hydrogen is a liquid at some 35 degrees above this so-called absolute zero; but we shall find some other properties of bodies converging on the same point, which is also of importance as the zero in thermodynamical calculations.

By taking advantage of what is known of the specific heats of various metals, it is possible to reduce temperatures in such proportion as to make them measurable by ordinary mercury thermometers. In Siemens' pyrometer, a mass of either iron or copper or platinum is placed in the flue, furnace, or crucible of which the temperature is required, until it has assumed the full temperature of the place. It is then rapidly transferred to a measured bulk of water, and the resulting rise in temperature noticed.

If  $M_1$  and  $M_2$  are the masses of the hot ball and the water respectively, including in  $M_2$  the "water value" of the vessel—

$S_1$  and  $S_2$  the specific heats.

$T_1$  the temperature to be measured.

$T_2$  the initial temperature of the water.

and  $T$  the final temperature of the same.

$M_1 S_1 (T_1 - T)$  is the heat lost by the hot ball.

$M_2 S_2 (T - T_2)$  is the heat gained by the water.

Since these are equal, we have—

$$T_1 - T = \frac{M_2 S_2}{M_1 S_1} \cdot (T - T_2)$$

The weights of the balls and the water are so adjusted that the temperature to be measured is read off directly on a scale on the thermometer.

In practice this method, which is fairly convenient of performance, is made uncertain by the fact that balls of either iron or copper burn at a red heat, and therefore are continually altering in weight, while balls of platinum are, especially at present "famine prices," too costly to be thought of.

Another method, based on somewhat similar principles, is that in which a current of air at known pressure issues from a jet in a form of injector and thereby draws in a regulated proportion of the furnace or flue gases to mix with the air of the jet, and so become reduced in temperature sufficiently for the use of a mercury thermometer. The graduation of such an instrument must be empirical, but when it has been performed good indications can, it is said, be obtained. Another similar instrument measures the heat of a furnace by the temperature to which a current of water of known amount per second is raised when passed through a pipe exposed to the heat.

In 1871 Siemens proposed to make use of the change of resistance to an electric current which is produced by heating for determining high temperatures.

As is well known—too well known, indeed, by anyone who has to do with electrical measurements—the resistance of a coil of wire varies with the temperature. It is for this reason that standards of resistance are constructed of alloys in which this variation is as little as possible consistent with the other necessary conditions of the case. Hence the use of such alloys as platinum silver, platinoid, German silver, and manganin, which, and particularly the last named, have a very low temperature co-efficient. On the other hand, pure metals have a much larger co-efficient, which is nearly the same for all, and amounts to nearly 0.4% for each degree centigrade of variation in temperature. Hence we see that if we suppose the resistance of a certain coil of platinum wire to be 20 ohms at the freezing point, each degree rise of temperature will increase this resistance by 0.08 of an ohm. One of the thermometer coils mentioned by Messrs. Callendar and Griffiths, in their paper in the "Phil. Trans.," for 1891, had a resistance of about 3.6 ohms, which would give a variation of 0.014 ohm for each degree, so that the exact measurement of any temperature is quite easy.

The apparatus constructed at first by Siemens had many weak points, and the very principle on which it depended was to some extent in doubt. So far, that is, as to whether the change of resistance per degree is different at different parts of the thermometer scale—and if different, what is the exact law of the variation.

A committee of the British Association examined the whole subject and reported in 1874, not altogether favourably to the method as then proposed. Since that time, however, much work has been done on the questions connected with the platinum thermometer, and such an amount

of knowledge has been accumulated, that with the modifications both in construction and in methods of measuring the alteration of resistance which have been made, the instrument has taken a very important place among thermometers. The papers by Callendar and Griffiths in the "Philosophical Transactions," for 1887 and 1891, are most exhaustive treatises on the whole subject, and should be referred to by anyone desiring a thorough knowledge of the matter.

The coil of platinum wire is formed on a strip of mica and is wound double, as is usual in resistance coils, to prevent the inductive action of a single coil interfering with the measurements. To the ends of such a coil wires must be joined for the purpose of the resistance determinations, and it is plain that as part of these connections must also necessarily be heated to a more or less uncertain extent when the coil itself is at the temperature of the experiment, the resistance of these leads will be altered and must be capable of measurement whenever an observation is taken. For this purpose the leads connected to the coil must be double, so that observations can be made, including, with the coil, various combinations of the connections.

For if the—

$R$  be the resistance of the actual coil,

$r_1$  and  $r_2$  the resistances of the leads connected to the one end of it, and  $r_3$  and  $r_4$  those of the leads connected to the other end,

The total resistance  $r_1 + r_2 + r_3 + r_4$  can be found by two observations, and that of the coil together with that of each of the two pairs of connections, will be found by two more, and thus the external resistance eliminated.

For accuracy of work a good resistance box is necessary, and Callendar and Griffiths recommend one of the dial form.

For technical use, a simplified pattern is made in which temperatures can be read off directly, say by unplugging resistances for each  $100^\circ$  and using a slide resistance for intermediate degrees.

By the use of the potentiometer method, however, the uncertainty arising from any unequal heating of the connecting wires is completely got rid of, the resistance being measured strictly between the points at which the so-called potential wires are joined on. On the other hand, the method requires that a current shall be all the time passing through the coil, which, therefore, will be heated to some small degree above the temperature of the surrounding space. This heating, however, is so small that for any ordinary purpose it may be neglected. A manganin wire is prepared equal in resistance to the coil when both are at the freezing point. This manganin coil will not alter in resistance at ordinary temperatures sufficiently to make any error necessary to take account of in the usual routine of technical work. Another great advantage of the potentiometer method is that, as the resistance of the wires connecting

the coil to the instrument does not affect the determinations, the readings may be taken in an office or laboratory in any convenient situation about the works.

To calibrate such a thermometer the resistance of the coil must be measured, first at the temperature of melting ice, and then at some higher temperature which has been accurately determined. This may be the boiling point of water, just as in the case of an ordinary mercurial thermometer. Then up to  $700^{\circ}\text{C}$ , the difference between the reading of the platinum thermometer and that of the normal air thermometer is very nearly represented, according to the paper of Callendar and Griffiths already quoted, by—

$$(a) \quad \delta \times \left\{ \left( \frac{t}{100} \right)^2 - \frac{t}{100} \right\}$$

$\delta$  being a constant for the particular wire and approximately (for thermometers however of a type rather different from that described above)

$$(b) \quad 1.57 + 15 \left\{ 1.3383 - \frac{R_1}{R_0} \right\}$$

where  $R_1$  is the resistance of the coil at  $100^{\circ}$  and  $R_0$  at  $0^{\circ}\text{C}$ .

Having measured these two resistances, the platinum temperature is given by the simple formula—

$$(c) \quad pt = 100 \frac{R - R_0}{R_1 - R_0}$$

The determination of another known temperature, say that of boiling sulphur under 760 mm. pressure—which has been very carefully investigated, and is taken as very nearly indeed  $448.53^{\circ}\text{C}$ —affords the means of determining  $\delta$  directly by substituting the known temperatures in (a).

For temperatures up to  $800^{\circ}$  or  $900^{\circ}\text{C}$ , a very handy adaptation of this platinum thermometer has been arranged by Messrs. Crompton, in which, by means of a differential galvanometer, the change of resistance produces a deflection of a needle which moves over a dial graduated directly into temperatures. This is not suited for accurate work, as the readings depend upon the voltage of the battery used, but where accumulator cells of fair size are used, so that the voltage may be taken as constant for some time, it gives a convenient means of controlling the temperature of flues or hot-air supplies.

The permanence of the platinum wire is of course a matter of the very greatest importance in these determinations, and a change of resistance after prolonged exposure to high temperatures was one of the causes

which led the British Association Committee to report somewhat unfavourably on Siemens' invention. It was found, however, that this change did not occur when the sheath surrounding the coil was composed of platinum, and it was eventually shown that it arose from the combined action of the atmosphere inside the iron sheath and the silica of the fire-clay cylinder on which the coil was wound. A thorough examination of the properties of the metal by Callendar proved that pure platinum, free from alloy with carbon, silicon, tin, or other impurities, when not subjected to strain or rough usage, possessed always the same resistance at the same temperature, notwithstanding heating and cooling, so that there appears no reason to suppose that these platinum thermometers, when constructed with due care as to the purity of the material, are liable to any alteration of zero similar to that which is so detrimental to the use of the mercurial thermometer as an instrument of precision. Although we are more especially concerned with the measurement of *high* temperatures, it may be of interest to notice that the platinum thermometer is much used in the estimation of the extremely *low* temperatures with which we are becoming familiarised, as the result of the brilliant researches on the liquefaction of gases which have been such a striking feature of the scientific activity, aided by mechanical ability, of the last two or three years. The resistance to the passage of electricity in the case of pure metals is another of those properties of matter which diminish as the temperature is lowered in such a way as to lead to the conclusion that at that point which we have previously spoken of as the absolute zero, viz.,  $-273^{\circ}\text{C}.$ , it would vanish. Thus the resistance of a platinum wire, which is, say, 1 ohm at the freezing point, becomes about seven times that when heated nearly to its melting point, while if cooled to the temperature of liquid hydrogen, boiling freely in the air, its resistance would be only about one-fiftieth of that at  $0^{\circ}$ .

Platinum plays an useful part in the next method of pyrometry which we consider.

It has long been known, having been discovered by Seebeck in 1822, that if a circuit be formed consisting of two dissimilar metals a current of electricity will be set up in the circuit so long as one of the junctions of the two metals is kept at a temperature different from that of the other. If a wire is the means of connecting the metals at one junction, the effect is exactly the same provided the two junctions with the wire are at precisely the same temperature; otherwise, of course, the inequality will set up another current which will interfere with that which we wish to investigate.

Such a juncture of bismuth and antimony has been extensively used for the detection of feeble heat radiations. Various forms have been given to the apparatus: from the battery of 36 pairs used by Melloni, with a sensitive galvanometer, to the radiometer of Boys, where the minute couple forms part of the hanging circuit which, by its swinging

within the field of a powerful magnet, measures the almost infinitesimal currents set up by the heat impinging upon the one junction. On a larger scale thermo-piles are used by which currents suitable for use in the analytical electrolysis of solutions can be obtained by the heat of a Bunsen's burner.

A couple made of wires of iron and German silver can be used for many purposes of thermometry where the temperature of a small space has to be determined, but is not, of course, available even up to red heat.

Fortunately, platinum and an alloy of platinum with 10 per cent. of rhodium, both of which metals have melting points beyond any temperatures which it is of practical importance to measure, form a thermo couple, the indications of which are in many ways extremely valuable for technical purposes. It was brought into notice some ten years ago by Chatelier, in the "*Journal de Physique*," and he there states that temperatures up to  $1,200^{\circ}\text{C}$ . may be measured to within  $10^{\circ}$  by means of such a couple.

Much work has been done since in the way of comparing such a couple with the air thermometer by Barus, in the United States; Holman, Lawrence and Barr, Holborn and Wien and McCrae, whose investigations have been published in "*Wiedemann's Annalen*," and in our own country by Dr. Roberts-Austen, whose beautiful work with it on the phenomena accompanying the solidification, or, as we may say, the 'freezing of metals have appeared in the "*Transactions and Proceedings*" of the Royal Society.

The construction of such a thermo-couple is as simple as possible—a wire of each metal is taken, long enough to reach out from the place of which the temperature is to be measured to a cool place, and a joint made, either by simply twisting them together, or better, by fusing in the oxyhydrogen flame. The method of insulating and protecting the wires will naturally vary with the degree of heat to which the couple is to be exposed. For flue temperatures, a thin walled glass tube for the protection, and a smaller glass tube as insulation for one wire will be sufficient. If temperatures above the melting point of glass have to be dealt with, iron or porcelain tubes must be used, and in the case of iron both wires must be kept away from the metal. This can be effected by taking strips of mica, say 6 inches long and half-inch wide, boring two holes at each end and threading the wires through them, so that they keep to their own edge of the strips, but pass through the adjacent holes in opposite directions. It is better to make the holes at the end of one strip coincide with those in the next and to pass the wires through the two strips, thus as it were rivetting them together. Mica, when it has been heated to a very high temperature becomes disintegrated, and will then bear no handling; but encased in a porcelain or iron tube, and with the outside connections made by binding screws fixed on a

collar, there is little to disturb the wires. I have tried tobacco pipes broken into lengths of about 3 inches to insulate the wires, but find that they are apt, by their weight, to drag the wires when these are softened by a high temperature. I have also made little clay cylinders with a double hole through them, but found them too much for the wires. The fact that the couple is still working quite normally at temperatures such that tobacco pipes soften and bend out of shape, and fire-clay glazes, gives an idea of the extended range of the instrument, as also of the difficulty attending the questions of insulation and protection. On the small scale for purposes of calibration little tubes of hard glass can be used up to the melting point of zinc; beyond that little protecting tubes of clay can be used—Roberts-Austen originally used specially-shaped crucibles, with a little glove finger, so to speak, in the bottom, by which the couple could be completely surrounded by the molten metal. I am informed, however, that he now uses little clay protectors and crucibles of the ordinary make.

The galvanometer used for the detection and measurement of the current produced should be of high resistance, and be what is called dead-beat, that is, the swinging of the indicator when disturbed from any position should very rapidly cease without much oscillation round the new point of rest. For technical purposes, an instrument of what is called the D'Arsonval, or moving coil type, is preferable from the fact, if for no other, that it is not affected by masses of iron or magnets, as of dynamos, in its neighbourhood. What I have used has been a galvanometer of the Ayrton-Mather patent of about 300 ohms resistance, which has worked very satisfactorily for general purposes. For special purposes, no doubt special instruments must be used; for instance, Roberts-Austen mentions that for his beautiful experiments on "Surfusion in Metals" ("Proc. Royal Soc.," vol. 63), a very sensitive galvanometer must be used, and special means adopted to prevent the deflection becoming too great.

The calibration of such a thermo-couple is quite simply performed as follows:—The galvanometer is set up with the "spot" of light sharply focussed on the scale, which is fixed at its proper distance from the galvanometer, the ends of the leads are clamped on, and the spot of light, which may very conveniently be the image of one of the filaments of an electric lamp, brought to the zero of the scale when all the junctions, that of the couple and those with the copper leads, are all at the same temperature. A crucible or ladle full of melted lead is then prepared, and the thermo-junction, suitably protected, plunged into it. The spot of light at once moves along the scale, and at once begins slowly to move back again towards zero as the metal cools. When the cooling has reached the freezing point of the lead the motion of the spot is arrested, since so long as there are both liquid and solid lead in contact in the crucible all the heat lost is taken from the latent heat, just as in determining the freezing point on a mercurial thermometer. The

scale reading where this halt takes place will be the reading which, with the same couple and galvanometer and the same total resistance of the circuit, will always indicate the number of degrees which the melting point of lead is above the temperature of the other end of the wires. The melting point of lead may be taken as  $328.8^{\circ}\text{C}$ ., and the other connections may be kept at a known temperature by being passed through glass tubes bent so as to dip into a beaker of water.

Another similar experiment must be made at as high a temperature as convenient. Copper is a good metal to use, as the melting point has been pretty well determined, and seems but little affected by the ordinary commercial impurities, and may be taken as  $1095^{\circ}\text{C}$ .

Instead of the melting point of lead the boiling point of sulphur may be used, and is indeed a more accurately known point of temperature.

Between the temperatures of melting lead and melting platinum, the curve connecting readings and temperatures is almost exactly a straight line, so that unknown temperatures can be determined from observed deflections.

The weakness of this method is that as the reading is made of a deflection, the galvanometer and its constants of resistance and directive force, and the distance of the scale, come into consideration, as also the total resistance of the circuit. No doubt, with a galvanometer of fairly high resistance the resistance of leads is only a small percentage, but yet it all counts and must be allowed for in calibrating, *i.e.*, the couple must be calibrated through the circuit on which it is to be used. The voltages in question are so small that the direct measurement of them is difficult; by a potentiometer method, however, Messrs. Holman, Lawrence, and Barr determined that when the cold junctions are kept at  $0^{\circ}\text{C}$ ., and the hot one at the following temperatures, the E.M.F. produced is, in micro volts:—

|                     | $^{\circ}\text{C}$ . | Micro Volts. |
|---------------------|----------------------|--------------|
| Water boiling       | ... 100.1            | 888.1        |
| Naphthaline boiling | ... 218.5            | 2218         |
| Sulphur boiling     | ... 444.8            | 5288         |
| Aluminium melting   | ... 660              | 8638         |
| Silver melting      | ... 970              | 14093        |
| Gold melting        | ... 1072             | 16002        |
| Copper melting      | ... 1095             | 16463        |
| Platinum melting    | ... 1760             | 30313        |

Having spoken of the weakness of the method, I come to the advantages, and they are for practical purposes considerable. The fact that the variations in deflection can be at once read off and converted into temperatures, will appeal to everyone—indeed, if everything is permanently fixed up, the scale could be at once graduated into degrees. Then Roberts-Austen has shown how beautifully the thermo-couple lends

show some of these things in their very simplest form. It is not the form in which they would be actually used in practice, but it serves to illustrate the subject. I have also some of the actual records which I have taken with the pyrometer. One is a record taken from the flue of a gas furnace. It shows comparatively no heat in that flue, and upon inquiring into the reason I found they had shut the furnace down during the night on account of some change of work. Every half-hour a clock lifted an arm and a spot was thus made, giving a time record and also the zero of the galvanometer. Another diagram, taken from drying stoves, and shows gaps in the traces occasioned by the cooling whilst getting out the waggons. A diagram with regard to the heating-up of a regenerator. Another interesting tracing shows the effect of a stormy night upon wires which were not properly bound together. I had taken two separate wires along the poles and the wires were blowing about, so that the induction of the earth, acting as a magnet, produced the extremely illegible trace. Another tracing represents the flue temperatures from some boilers before and after the use of Green's Economiser, showing the difference in flue temperatures. I will now give you an experiment showing how the Siemens Recording Pyrometer is used. [Experiment.] Now we will have an experiment showing the use of the Chatelier couple. I have threaded a platinum wire and a platinum-rhodium wire, through a strip of mica to insulate them, and have found it a very effective insulation for moderate flue temperatures. Another way of insulating is simply to slip one of these wires into a glass tube. You can put that apparatus into your flue and keep it in for weeks, reading temperatures at any moment you like. With regard to the apparatus on the table, I shall be able to show how it works. I screw the ends of the wire on to the terminals of the galvanometer. The apparatus shows a spot of light moving on a cardboard screen, and its movement varies in accordance with the temperature of the small piece of lead which I am melting. When the spot moves to the right, it shows that the whole of the mass of lead is warming. It is now pretty steady, which indicates that there is a little melted lead round the bottom of the basin. The lead is now all melted and we allow it to cool; as the junction cools, the spot moves off to the left. A great advantage is the very small amount of matter you have to heat. It is, therefore, an exceedingly rapid method, for as soon as the mere junction of the fine wires is hot, you have your reading. It is not as though you had to occupy three or four minutes to heat up a large mass, it is practically instantaneous.

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## THE DISCUSSION.

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THE PRESIDENT: We have had a very useful and interesting paper on the measurement of high temperatures. It is a question of importance, and we all, as practical men, shall find some use for the information

given. I don't think we shall have a great deal to discuss this evening, though I dare say some of you may have a few questions to ask. If so, I shall be glad if you will put them, for I am sure Mr. Waller will be pleased to answer them.

Mr. J. W. HALL : I quite agree with you, Mr. President, that we have had a paper of an entirely new type to us, and one which is exceedingly interesting. We all, for years, have been wanting to get means of measuring high temperatures with accuracy. In annealing and tempering steel gun-tubes, and in some other cases, the material has to be treated at an exact temperature varying only to the extent of a very few degrees, if the best results are to be obtained. So, to have some means of automatically recording the exact temperature, is exceedingly useful and valuable. Mr. Waller has told us how we can measure very high temperatures ; but I should like to ask how he reads temperatures above the melting point of platinum, which I understand from his paper, is 1,760 degrees centigrade. I should like to know if there are any means of getting at temperatures above that, in any manner except inferentially. I mentioned that we were going to have this paper to a friend of mine who is an electrical engineer. He coupled up two wires in connection with a galvanometer he had in his dining room, made a few simple adjustments, and so sensitive was the arrangement that when he even put his finger on the wires you saw a spot of reflected light travel along the wall. It gave a good idea of the extreme flexibility which an appliance of this sort must have. There are no doubt many here who would like to have some information as to how the apparatus is used in actual practice.

Mr. TUCKER : With respect to Mr. Waller's paper, two points which will appeal to you regarding the working of the thermo-couple, are its simplicity and its accuracy. As Mr. Waller said, in its primal form hardly any apparatus could be more simple than this very beautiful pyrometer. I am glad that circumstances permitted of my bringing before you the illustrations which would appeal more particularly to you, namely, the illustrations from *Engineering* this week. They showed what I have previously advocated, namely, the application of this pyrometer to practical foundry work, I feel satisfied that the introduction of this instrument cannot fail to be combined with the most valuable results in such work. It is obvious that the quality of any casting, particularly chilled rolls, must be greatly influenced by the temperature at which it is cast, and you remember you saw a picture of a man taking the temperature of the cast-iron during a casting process. A workman can really leave his ladle standing and only pour it when a certain temperature has been indicated by the pyrometer. You can in that way work always at a definite temperature, and it seems to me that failures in chilled rolls and other castings must necessarily be less frequent if such careful and systematic working is undertaken as is possible with the instrument which Mr. Waller has brought before us this evening.

Mr. W. J. HUDSON: I have had some experience with the Roberts-Austen pyrometer, and would like to add my testimony to the very valuable character of the instrument when used in connection with blast furnace work. The instrument I used would connect to three furnaces, either singly, or two or three together; and gave a photographic result each morning of the work done during the previous twenty-four hours. The records were really valuable. I could know almost to a minute the time at which the workman changed his stove. I knew by a slight rise in the downward movement of the light when any other furnace was taken off blast. There were also several other indications of what was going on—things which, though little, were very important and very useful at times. Another useful application of the instrument is when it is fixed to take the temperature of the escaping gases. Sometimes you are told that so many charges have been put in and you have to believe it, but by this instrument you can check the number of charges. For instance, as the man charges the material into the furnace, down goes the temperature of the escaping gas, and along the diagram you get the line which indicates this drop of temperature. Then the temperature rises until the next charge goes in, and so on. These photographs do not always agree with the charge book.

THE PRESIDENT: Gentlemen, I am sure we must all thank Mr. Waller for the kind manner in which he has come before us this evening and given us this most interesting paper. I shall be pleased if you will pass a vote of thanks to Mr. Waller for having given us this interesting paper.

The resolution was seconded by Mr. PIPER, and carried unanimously.

Mr. WALLER: I am delighted that you have found something in what I have brought before you this evening that has interested you. Personally, I have been very much interested in this thermo-couple, and have found it of great use, and I am exceedingly pleased that others using it in connection with quite different operations have also found it useful. As to the question of ascertaining temperatures that are beyond the melting point of platinum. Some high temperatures have been measured by the intensity of the emission of heat, but that seems to be a somewhat doubtful method; but you see temperatures recorded as high as 3,000 or 3,400 degrees. I should like to know whether the couple which was in use when Mr. Hall saw the galvanometer affected by the heat of the hand was one of these couples?

Mr. HALL: I cannot tell you.

Mr. WALLER: Either it was a very sensitive galvanometer, or else some other couple was used.

Mr. HALL: A simple arrangement of copper and iron wire.

Mr. WALLER: I have only to thank you very much for the kind way in which you have listened to me, and I trust it may help some of you over difficulties in practical work. We all find our difficulties, and if we can help each other over them, so much the better.

The fifth Meeting of the Session was held at The Institute, Dudley, on Saturday, the 18th March, 1899.

Mr. H. LE NEVE FOSTER (President) occupied the chair.

The minutes of the previous meeting were read, adopted, and signed.

Mr. J. H. WHITTAKER then read the following paper, and exhibited a collection of appliances—some of which were, for a short time, put in motion.

## ELECTRICITY IN MINES AND IRONWORKS; With Special Reference to Three-phase Currents and Motors for Power Transmission.

By J. H. WHITTAKER, A.M.I.E.E.

Our subject as set out in the title of this paper is so large a one that it would be quite impracticable to attempt to thoroughly deal with it in the hour allowed for this meeting. I propose, therefore, to practically confine my remarks to the particularised part of our subject—Three-phase currents and three-phase transmission of power. I would like, however, to make a few general statements on the full subject. Electricity in mines and ironworks has been practically established for a number of years. Its use has been established on the continuous current system, and where properly installed and care having been exercised in the plan of installation, so that the plant is fully large enough to meet the maximum demands of the work it is intended to do, it has generally given great satisfaction. There have been many failures, and they have been overcome. The great difficulties have been lack of proper strength of parts of plant and inability to withstand dampness and water.

Electric plant, a few years ago, was considered more as scientific apparatus, and was made accordingly, oftentimes in a laboratory fashion. Experience, however, is the best of teachers, although charging highest fees. Electrical apparatus of all sorts is now designed as machinery, and electrical engineering has become strongly allied to, or indeed a part of, mechanical engineering, so that builders of electric plant remember that they are designing and building machines, whose most striking feature must be mechanical strength.

Fortunately it is quite possible to attain the highest electrical efficiency at the same time as greatest mechanical strength.

A glance at the armature of the continuous current motor on the table at the close of meeting, will show that the windings are now embedded in the iron completely and are out of harm's way; this can be done in dynamos and motors for all purposes. The continuous current motor crane in large iron and steel works, of which the Three Motor type is generally most satisfactory, is well known and needs no comment. Iron-shielded or enclosed motors, for all rough work as pumping, hauling, driving portable drilling or other machinery, in mines and ironworks are

also well known. They are capable of withstanding very rough usage, and can be made absolutely airtight if necessary ; in which case, however, they must be of large size in proportion to the work they are called upon to do. They are generally made with the upper part hinged or capable of being lifted away for examination or repairs to armature. Although enclosed, they may be made to run quite cool, and are especially suitable for use in wet, damp, and dirty positions. The flexibility of the system of power distribution, the high commercial efficiency, the ease of laying cables compared with steam or air piping, of moving the motors to any angle, or in any direction for coal cutting, or any work required, the safety and simplicity of well designed plant ; these points have been dealt with many times and have become matters of every engineer's knowledge. Watertight telephones, strong and capable of withstanding the roughest wear for years ; damp-proof and gas-tight bells and signal apparatus, watertight and gas-proof lighting fittings, are quickly becoming quite common.

The concentric system of wiring has many advantages, and deserves greater use, the inner cable only is, as a rule, insulated, and the other cable is laid concentrically to the inner, left bare, or is sheathed with lead and oftentimes is armoured with steel tape, laid spirally outside the lead as a protection to the whole ; this is, of course, expensive, but is remarkably free from breakdown, even with the roughest possible wear. A few specimens of the above-mentioned articles are laid on the table for inspection by anyone interested.

Turning now to machinery for power transmission, we may observe that the brushes and commutators are the great source of anxiety to owners of continuous current dynamos and motors. As a rule the dynamo or so-called generator is fixed in a clean, dry engine room, a man is constantly in attendance, and the brushes and commutator have every care and attention ; the brushes are carefully trimmed and adjusted weekly, and the commutator trued up whenever showing signs of flats or wear, to prevent sparking. Not so the motors, they have the harder work to do, are subjected to greater strains, are generally placed in dirty and wet positions, and yet have very much less attention. The brushes become worn and out of place, sparking ensues, and unless attended to promptly the commutator is ruined.

This trouble may be obviated by care on the part of the attendant, the brushes made to last a year at least, and the commutator several years ; still *there* is the vital part of the machine, and, unfortunately, motors do not get the care that is necessary to attain long life. This brings me to the larger part of our subject—Three-phase current machinery.

This is comparatively new in this country, only about a dozen plants in all being in operation. On the Continent, in America, and in South

African mines, however, numerous and large plants are running or being installed.

The field for three-phase currents is undoubtedly in power distribution and transmission, although lighting also is being successfully carried out with the same plant as used for motor purposes. The chief characteristic of three-phase generators and motors is that no current passes through the rotating parts, consequently they require no brushes or commutator of any description; thus ensuring a much higher degree of durability and safety than is possible with any other electro-dynamic machines.

In describing an electrical power transmission plant it is natural to start at the generator or power house.

Three-phase generators of the best type, as made by the Oerlikon Company, on the Continent, and the General Electric Co., Limited, of London, to whom I am indebted for the electros and the motor shown, have armatures consisting solely of iron or steel, and have no windings thereon whatever, that is, the rotating portion. This is not, strictly speaking, the armature, but is the inducer of the current, and is correctly called the inductor.—See Fig. 1.

Both the field windings and armature windings are stationary, and therefore are connected directly up to screw terminals on the base of the machine. The windings of the armature proper are spaced so as to have electro-motive-force generated in them, varying in phase  $120^\circ$ , and have their free ends connected up to the three terminals, as before mentioned. Having no commutator, the currents given are of alternating nature, thus the current in each phase rises to its maximum and falls to zero, in a two-pole machine, twice every revolution, i.e. on passing the N. and S. poles, and as the windings are divided into three and spaced 120 degrees behind each other, the maximum voltage will be obtained at each terminal, varying 60 degrees.

In common with all alternating current generators, the fields are separately excited; generally by means of a small direct current machine, directly connected to the shaft of generator, and fixed on an extension to the base plate.

The electro-motive force capable of being generated by this class of machinery is very high. During the last few years a large number of generators have been made and fitted to work at various tensions up to 5,500 volts, and have, I believe, given entire satisfaction.

The machines are made of the best materials and workmanship obtainable, and the bearings are self-aligning, and self-oiling.

The second section of a power plant, is the line or mains. Three wires must of necessity be used on the line, but as they may be of smaller diameter than if continuous current was being used, a saving of copper is effected by the use of three-phase currents; except in the case of low

pressure distribution where the saving in copper is nearly counterbalanced by the extra cost of erecting the third wire.

Where it is required to transmit the current only 200 to 300 yards to the motors, the E.M.F. may be only 100 or 200 volts; if over 300 yards, and up to about half to three-quarters of a mile, 500 volts may be used; but for longer distances, the generators should give 100 or 200 volts, which pressure may best be handled for lighting purposes at or near the power house, but the current intended for transmission should be raised by means of a transformer to 2,000 or 5,000 volts, or higher, and transformed down again before being connected to the motors.

A transformer for raising or reducing the E.M.F. of three-phase currents, consists of three iron cores suitably wound with well insulated wires, the magnetic fluctuations due in the iron to the alternations of the primary current, induce currents in the secondary of similar alternations, but of higher or lower voltage as the case may be. There are no moveable parts whatever.

If a plant is for power transmission only, the generator may give direct to the line an E.M.F. of about 5,000 volts, and the motors at the end of line receive the full voltage, less of course the drop on the line.

It is to the merits of the motor, however, that I wish particularly to call your attention. The line wires are led directly to the terminals and windings of the stationary portion only, of the machine. The working current does not pass through the rotor or armature, or come in contact with it in any way, but is delivered to the stationary windings, and there produces a rotating magnetic field, which causes the rotation of the armature or rotor; the speed depending on the number of poles on the stator, and the frequency, periodicity, or number of complete alternations per second, of the current used.

Fig. 2 shows the armature or rotor of a three-phase motor. It is simply a laminated cylinder, having holes round round its periphery, in which are placed solid rectangular bars, connected at either end by a copper or brass casting. These bars or conductors instead of carrying the full potential of the circuit, as in a continuous current motor, have only a difference of potential of a few volts. Insulation is not absolutely necessary, even on the conductors, but a slightly higher efficiency is attained by covering the conductors with a thin layer of tape, simply to confine the induced currents to the copper; should this fail, *i.e.*, become removed by any means, the motor will go on working, apparently as well as before, without sparking or heating. There is no need for binding wires or string, as there is nothing to become loose; the centrifugal force cannot drive the conductors against the poles or loosen them in any way. Not only is such a machine simplicity itself, but high voltages are entirely dispensed with, burnt out armatures are impossible, and as the motor is commutatorless and brushless, we can dismiss, once for all, from

our minds all anxiety as to sparking, even with sudden overloads; sparking cannot possibly occur, except by forcibly tearing out the conductors from the terminals or otherwise cutting the wires.

Fig. 3 shows a complete motor of the type adopted for 12 H.P. size and upwards. The stator corresponds to the field-magnets of a continuous current motor, both can be made reliable, and as a rule give little or no trouble. The bearings are self-aligning and self-oiling of the loose ring type, dipping into wells of oil in the pedestal, and being rotated by the shaft carry the oil to the top of shaft and bearing. The motors require no attention whatever, except once a month, and then only the addition of a drop of oil.

The only friction and consequent wear is the friction of the bearings, and if these get their proper supply of good oil, nothing else is required. The speed is constant to within 4 per cent. or 5 per cent. at all loads, and the motor will stand 20 per cent. overload without loss of speed. The smaller sizes up to 10 H.P. are usually started by simply switching them into circuit by closing a three-pole switch, and they will start against full load.

The larger sizes it is found advisable to start through resistances of some kind, either automatic transformer and a two-way switch, giving the stator winding only half-full voltage until it has attained a fair speed with part load, and then switching on full current to take full load; or similarly starting through liquid or metallic resistance, the motor running free or with about half load as before stated,

With large machines, required to start with full loads, it is necessary to have a resistance and switch connected to the rotor conductors through three slip rings and sliding contacts, to be used only at starting. The full current is switched on to the stator windings, but resistance is put in circuit with the rotor, sufficient to keep down the current to just sufficient to allow the rotor to obtain maximum starting torque. This current will be very little in excess of the maximum current required for the motor to perform maximum work, and will thus cause no strain on the generator, mains, or engine.

At the front of Fig. 4 such a resistance is shown, also the rings on end of the shaft. To start the machine, the three-pole main switch is first closed, all the resistance being in circuit, this is gradually switched out whilst the machine runs up to normal speed; when this is obtained the resistance is short-circuited, and the three brushes lifted.

The motor will then run free without any sliding contacts or resistance, unless it is desired to regulate the speed of the motor, when the sliding contacts may be left on and the speed regulated by the resistance and switch. There are thus three ways of starting three-phase motors:—

- 1.—Motors up to 10h.p. to be switched directly into circuit.

- 2.—Larger sizes required to develop only about twice their normal turning effort at starting ; to have resistance in circuit with their stator or field coils.
- 3.—Large motors required to develop their maximum torque at starting against full load ; to have sliding contacts and resistance in rotor, to be used for starting purposes or regulating speed only.

Compare now two power plants of several hundreds h.p. It is generally found that motors below 12 h.p. predominate in number. If it is a three-phase plant these will have no resistances ; of the larger sizes, the majority will not be required to give maximum torque at starting, these may have transformers and simple change-over switches ; only a few will need sliding rings and resistances.

The continuous current plant, however, would require 20 to 30 commutators, 20 to 30 resistance boxes and switches, and the motors would require over a hundred brushes and brush-holders.

The efficiency of three-phase plant is at least equal to that of continuous current machinery. The efficiency of a 100 h.p. generator would be 90 per cent. ; the efficiency of a similar-sized motor would be a similar figure at full load, and about 83 per cent. at half-load. A 10 h.p. motor would show 87 per cent. at full load, and about 80 per cent. at half-load.

If long distances have to be covered, high voltages must be used, which may be obtained directly from the generator, or by means of step up transformers, as previously stated. By the use of 5,000 volts, obtained direct from the generator, 100 h.p. may be transmitted by three-phase current to the motors at a mile's distance with a loss of only 3 per cent. in voltage, with copper lines of No. 10 S.W.G., or  $\frac{7}{16}$  strand, and No. 13, S.W.G. would transmit 100 h.p. with a loss of about 6 per cent.

If transformers are used, the efficiency will be lower for the whole plant, but only by about 3 per cent. in large transformers, and even in small transformers, of say 10 h.p. capacity, the loss would not exceed 6 per cent. This is very little indeed considering the saving in copper effected ; this saving is indeed considerable, as I will endeavour to show.

Where power has to be transmitted distances over a mile, continuous currents are at a disadvantage, owing to difficulties of maintaining the insulation of the armature windings and commutator on high voltages. The highest voltage of continuous current in actual work in this country is, I believe, about 2,000, and with this voltage the machine has to be treated very carefully. The current having been conveyed to the point of distribution to the motors, must be reduced to say 500 volts ; this is effected by means of a continuous current transformer, which is really a motor at 2,000 volts driving a dynamo which will give nearly four times the current in amperes at one-fourth ( $\frac{1}{4}$ th) the voltage, viz., 500 volts. Such a machine has two commutators and two sets of brushes. For transmitting small powers, it may not be necessary to use such a plant

i.e., at 2,000 volts; but for say 500 horse-power to be transmitted one mile, a current of 200 (two hundred) amperes, roughly speaking, would be required, and this would need a cable of about  $\frac{1}{2}$  strand S.W.G., weighing nearly four tons, the double cable, per mile uninsulated, and costing, unlaidd, about £1,000 (one thousand pounds), and there would be a loss of about 90 volts, or  $4\frac{1}{2}$  per cent. in the cable. Using three-phase plant, 500 horse power could be transmitted one mile by cables of  $\frac{1}{2}$  strand S.W.G., and using the same class of cables, insulated, lead covered and steel armoured, with the pressure at 5,000 (five thousand) volts, the loss would be less than  $2\frac{1}{2}$  per cent.; the copper would weigh  $1\frac{1}{2}$  (one and one-half) tons, and the finished cable would cost about £500 (five hundred pounds). These figures are only approximate, but are very nearly correct.

In the case of continuous current transformation, you would lose at least 10 per cent. in the transformer, but with three-phase currents you could use the full voltage on motors of 25 h.p. and upwards, or if it must be reduced, the loss in transformer would not exceed four per cent.

There is always a risk in the use of high voltages, especially with unskilled attention, and it is generally advisable to transform down before connecting to motors.

As previously stated, the transformers are very simple, are completely cased in, have no moving parts whatever, are self-regulating, and need absolutely no attention.

The voltage named is not by any means the limit of three phase pressures; single phase alternating currents have been used for years in London, at 10,500 (ten thousand five hundred) volts, and there is no special difficulty in doing the same with three-phase currents if required in some large scheme, when of course the size and cost of cables would be still further reduced.

These matters are outside the scope of this meeting, however, a higher voltage than 500 (five hundred) is not generally required in ironworks or collieries; except in the case of a number of mines and works requiring power, belonging to the same firm, when the high voltages would show great economy, and they may be used with transformers with perfect safety.

#### LIGHTING.

For lighting direct from the same mains, three-phase currents are not quite so advantageous as continuous or direct currents.

Where light is most important a three-phase simple plant is not altogether satisfactory unless the motors are small, but if the proportion of lighting to power transmission is small, and the work lighted not of the most particular kind, current for lighting can be taken from the same mains, providing always that the voltage is not too high for lighting incandescent lamps.

The lamps must be equally divided between the two outer and the inner wire, to preserve a balance of current over the system as in continuous current three-wire systems, or a fourth wire may be run back to the generator, which will then be fitted with a fourth terminal. For arc lighting it is always well to transform the current by means of a rotary transformer, which is really a three-phase motor driving a continuous current dynamo, into direct current; alternating arc lamps not being nearly as efficient as continuous current lamps.

The efficiency and ease of transmission of three-phase currents offer strong inducements, however, to engineers to adopt them for transmission for any purpose, and to use rotary transformers, giving out continuous currents at low voltage at the point of distribution for lighting purposes. This arrangement is being adopted in many places, where motive power is at a distance from the consumer.

The Manchester Corporation is now having three-phase generators put down at their lighting station in the city to transmit currents at high-voltage to the outlying districts, Salford, Moss Side, &c., where it will be transformed into continuous currents at 250 volts.

Dealing, however, only with mines and ironworks plant, when lighting direct from the same mains as used for power, the main disadvantages are the arrangement of lights in two equal circuits, which is after all not a very serious matter, and the momentary flicker of the lights at the time of starting, or sudden loads on the motors; but this disadvantage is equally met with with continuous current plant under similar circumstances, and considering the saving of copper, the higher efficiency over long distances, and most of all the practical indestructibility of the machinery, I contend that the three-phase system has many advantages to recommend it, and that the disadvantages are of comparatively little weight.

Nothing more remains except a brief statement of particulars of several plants in operation, and to describe the other diagrams. The General Electric Co., Ltd., has a three-phase plant at Manchester. The generator has an output of about 100 h.p., there are eight motors driving shafting, boring machines, radial drill lathes, &c.; they are fitted in several cases on brackets on wall near ceiling, and are only inspected once a month; the author has never seen machinery working so well with so little attention. In addition to the above, there are three motors 6 h.p., 4½ h.p., and 1 h.p., used on a 5-ton 3-motor crane.

Fig. 5 represents this crane, the speed is reduced by worm gearing running in an oil bath. The 6 h.p. motor for lifting and the 1 h.p. for traversing are mounted on the crab; they will stand a very heavy overload or sudden reverse without damage. The 4½ h.p. for longitudinal travel may be fitted either at the centre or the end of crane as may be convenient, and is usually arranged for two speeds, full and half-speed, which operation

is performed by a throw-over switch; the starting and reversing is done by a second throw-over switch.

There is a plant for both lighting and power transmission at Bootle, near Liverpool. It has been running for about two years. There is no reserve generator, or reserve stock of spare parts of any description. They have one generator of 165 h.p. driving nine motors of various sizes. An extension of the plant has just been made, consisting of another generator and two 48 h.p. and one 60 h.p. motors. There are 200 lamps connected on to the same mains and they are eminently satisfactory, only flickering when the large motors are started against a heavy load. A three-phase plant has been fitted for the L.N.W. Ry. Co. for power in the goods yard, and the current is transformed by rotary transformers to direct current for arc lighting.

Fig. 4 represents one of three triplex single action pumps with plungers  $6\frac{1}{2}$  inches by 8 inches coupled direct by single reduction gear to 35-h.p. motors, supplied to the Vögestruis mine in South Africa. As the mines are very wet the motors were made with watertight and ventilated covers. Twelve direct driven pumps of somewhat smaller size with 20 h.p. motors are also being used by the same company.

Three 35 h.p. and eight 20 h.p. pumps, with generators, &c., have also been sent from England to the Knight Central mine, also a similar plant to the Witwatersrand mine in South Africa. The York Gold Mining Co. have a plant with two generators and five or six motors for various purposes.

Fig. 6 and 6A, show one of three horizontal 5 inches by 9 inches duplex pumps made for the Consolidated Goldfields Company of South Africa. Each pump is capable of raising 200 gallons 60 feet per minute. The motors are three-phase 9 h.p., running at 1,150 r.p.m., reduced through double reduction gearing.

Fig. 7 represents the arrangements of an electrically driven coal cutter. It is driven by two 10 h.p. three-phase motors wound for 500 volts, and run at 960 r.p.m., this being reduced through treble reduction gear to 9 r.p.m. at the cutter. The diameter of the cutter wheel is 5 feet 8 inches. This is in successful operation at one of the collieries of Messrs. Pope and Pearson, Ltd., Normanton. There are several other plants in the country, one at Cambridge, one at London, several in Ireland, and although so few, there is satisfaction in knowing they are doing well. There are many plants on the Continent, one of them being a three-phase tramway system with over-head trolley lines. I have every confidence in stating that the superiority of the three-phase system for power work will soon make itself felt, and I hope the Midland and South Staffordshire engineers and works' managers may be among the first to reap something from the advantages of the system.

## THE DISCUSSION.

**THE PRESIDENT:** Apologies for non-attendance have been received from Mr. F. Brown, Walsall; Mr. J. C. Vaudrey, Birmingham; and from Mr. Thomas Parker, Wolverhampton. The members of the Institute will agree with me that there is no need for an apology for the paper which has been presented to us this evening. We are all aware that electricity is being employed more and more every day in every sphere of life. We have it in our streets, houses, and workshops for lighting purposes, and it is also being increasingly employed for power purposes both as regards fixed machinery and movable machinery, such as railways, tramways, motor car propulsion, etc. The subject of the three-phase motors is entirely new to most of us, though I believe we have present this evening some gentlemen who will be able to supply us with some electrical information on the subject which has been presented to us in so comprehensive and lucid a manner by Mr. Whittaker. There are one or two points upon which I should like to glean some information which have not been touched upon in the paper. One is the question of the applicability of electricity in this country for rock drilling purposes. In making inquiries a few days ago into this matter I was informed that drilling has not hitherto been carried out in our country by electricity, but I hardly think that this is correct and should like some authoritative pronouncement upon it. Of course, in coal cutting and numerous other mining purposes the new power is being employed in England as well as on the Continent and in America, but to what extent it has yet got into use for rock drilling purposes I am not aware. On the Continent, and especially in Sweden, I believe such drills are being worked with very great success. It seems likely that compressed air and other means of rock drilling will in the future have a severe competitor in electricity, and the subject is therefore one of considerable interest. A few days ago I saw some thirty or forty rock drills which were being driven under compressed air and which were executing their work very creditably; but, by and by, we shall look for an extension of electric rock drilling in England similar in some degree to the footing which the process has obtained in Europe and America.

**MR. W. L. SPENCE:** I think I can answer to some extent the inquiry which has been made by the President. Rock drilling by electricity is being carried on at the present time in some of the ironstone mines in the Cleveland district; but, as the President has remarked, there is certain to be a further extension of the use of this class of motive power for drilling purposes. The communication which has been laid before the Institute by Mr. Whittaker to-night is full of suggestive possibilities; but, speaking from my own experience in connection with electric transmission work, I question the soundness of the views which have led to his support of the three-phase current system. Candidly, I should say

that I am most distinctly a direct current man, and consequently I have listened with no small amount of amusement to some of the arguments which have been adduced in favour of the three-phase motors. One point particularly occurs to me—small motors are always selected by its advocates as a good example of the simplicity of the three-phase system—and it is very right that they should be, for small three-phase motors are very simple in fact. But when the question of the applicability of the same system to large motors comes up the position is immediately altered, and the advantages are by no means realised. Especially would this be the case in iron and steel works, where most of the motors would have to be fitted with contact rings and be started through resistances. When I last visited Switzerland, in 1896, I inquired closely into the state of electric engineering in that country, where polyphase work has received great attention, and I found that in many cases in large factories the most trying motor work—overhead traveller crane operation—was entirely removed from those circuits which were used for lighting purposes. In some engineering shops there the shaft motors, those constantly running and not subject to varying loads, were certainly on the lighting system; but the majority of the motors were mounted in such a way that the belts could be eased off temporarily for starting. Doubtless there have been some changes and improvements in the methods of running since 1896, but I know there would still be found many difficulties with three-phase plants. Mr. Whittaker, in the third paragraph of page 7 in this paper, states “The smaller sizes up to 10 horsepower are usually started by simply switching them into circuit by closing a three-pole switch, and they will start against full load.” This condition is usually advocated as one of the great advantages attaching to the three-phase system; but it is within my knowledge that in the largest electrical engineering works in this district direct current shunt motors, which have been proved in practice to be the equivalent of three-phase motors, have been worked for many years upon identically the same lines. I should, therefore, like to emphasise that the advantage in this particular of simplicity claimed for the three-phase system is not entirely confined to that method. Mr. Whittaker, on page 8, in the fifth paragraph, states further, “The efficiency of three-phase plant is at least equal to that of continuous current machinery. The efficiency of a 100 horsepower generator would be 90 per cent.” Mr. Whittaker’s statement may be correct or not; the efficiency of a 100 horsepower generator may be 90 per cent. or it may be more; but I may remark that if the efficiency is not a good deal higher than this, then it is not equal to that of direct current machinery of like capacity. In paragraph 8, on the same page, Mr. Whittaker states “The highest voltage of continuous current in actual work in this country is, I believe, about 2,000.” This is correct. But it may be interesting to state that recently some 800 h.p. of direct current transformers have been built and successfully tested while running at a pressure 3,200 volts on each commutator. On

page 9, second paragraph, Mr. Whittaker states "In the case of continuous current transformation, you would lose at least 10 per cent. in the transformer; but with three phase currents you could use the full voltage on motors of 25 h.p. and upwards, or if it must be reduced, the loss in transformer would not exceed four per cent." Now such a loss as 10 per cent. in the transformer is very high indeed. If these machines are used as "reducing" transformers, the efficiency of transformation goes up to 96 per cent., and the capacity of the transformer is doubled. This system is now being installed in the new City and South London Railway line. The generating pressure is 2,000 volts, and a constant terminal pressure is given (with constant station pressure) some three, four, or five miles away. The capacity of the transformers is double for a given size what it has hitherto been in installations of a similar kind. In the fifth paragraph on the same page Mr. Whittaker states that "single-phase alternating currents have been used for years in London, at 10,500 volts, and there is no special difficulty in doing the same with three-phase currents, if required, in some large scheme." In that statement Mr. Whittaker does not credit the alternating system with all he might for I have seen direct current installations working at 15,000 volts. He might have gone much further than he has in this particular. In that part of his paper dealing with "Lighting," Mr. Whittaker states "The lamps must be equally divided between the two outer and the inner wire, to generate a balance of current over the system, as in continuous current three-wire system, or a fourth wire may be run back to the generator, which will then be fitted with a fourth terminal." I do not understand this remark, and should like a little explanation of it from the author—to get a tolerably good lighting effect on the three-phase system it is essential to have four wires. One other point I would mention, in conclusion. It is that polyphase induction motors have a low "power-factor," *i.e.*, they consume, apparently, much more current than corresponds to the real energy supplied to them. This reacts unfavourably on the generators which must be installed in sizes far above the true needs of the case if only synchronous motors were used.

MR. G. L. ADDENBROOKE: The members of the Institute may remember that about this time last year I contributed a paper to the Institute with reference to the project of the Midland Electric Corporation for supplying power to the Staffordshire district. At that time the exact system to be adopted had not been determined on, but since then the matter has been gone into very carefully, and last autumn, as representing the company, I spent some time on the Continent investigating electric power system in operation in Switzerland and elsewhere. As the result of this inspection and of our investigations in other directions, it has now been determined to adopt permanent by the three-phase power system, which has been advocated by the author of the paper this evening. I am, therefore, in hopes that before very long we may see three-phase transformation in operation on a large scale in this district.

Referring to the paper itself, I should like to say that I do not consider that the author laid enough stress upon the enormous extent to which two and three-phase power transmission is already employed on the Continent and in America. Some figures lately came into my hands which enabled me to make a rough estimate of the extent to which these latest systems are in operation abroad, and I find that on the Continent and in America combined there must be between three-quarters of a million and a million horsepower already in use, generated and transmitted by two and three-phase currents, and very much of this power has been employed for some time past. The author has mentioned a number of three-phase current plants which are in operation in England, but I find that he has omitted one of the largest. This is the one at Messrs. Thomas Richardson and Son's marine engine works at Hartlepool, who have a plant of 1,200 h.p., and it may be of interest to state that this firm are just now supplying a plant to the Patent Shaft and Axle-ree Company, of Wednesbury. Coming to railway running, I may mention that the three-phase plant for the Central London Underground Railway will be of about 10,000 h.p. The Metropolitan Electrical Company, whose works are close to Willesden Station, are laying down a two-phase plant, which will be of about 7,000 h.p. I am sorry to say that all this plant has been supplied from America, and a very large proportion of the plant which Mr. Whittaker has described will also come from that country. This, however, is not so much the fault of English machinery engineers, but is due to the cruel conditions with which they find themselves surrounded, owing to the way in which the development of the British industry is being crippled by the selfishness of Municipalities, who insist on keeping the lighting and power schemes in their own hands, and then proceed very slowly, while in America, and also to a large extent on the Continent itself, the electric supply industry is left much more free and unfettered to develop itself as rapidly as it desires. In this country the authorities, both local and Imperial, seem delighted to put every obstacle they possibly can in the way of private enterprise with the result, as I have stated, that three other nations are a long way in the van. The figures which I have given will show that there is already a vast amount of two and three-phase current power being successfully utilised abroad, so much so, in fact, that the new power is nearly transforming the industrial face of the world outside Great Britain. As regards the voltage at which these currents can be generated; when I visited Switzerland last autumn I was shown some three-phase generators which were to be employed in generating currents at 13,000 volts. A well constructed two or three-phase motor designed on ordinary lines can be made to start with two and a half times its full running torque, and it possesses this very great advantage, that it will also stand something like two and a half times an overload above its fully rated capacity before it comes to rest, and there is then no burning up. Another cardinal benefit to be obtained from

three-phase currents is that motors designed for this system will run very efficiently at even half and quarter loads. Now this is one of the chief recommendations attaching to electrical motors of any sort. As Mr. Whittaker has described, there are only two bearings; the whole machine is perfectly balanced, and the amount of friction is almost nominal. With the steam engine on the contrary, in some cases 15 per cent. of the full load is lost in friction. Now I turn to another point in Mr. Whittaker's paper, which I should like to bring to your notice very carefully because it illustrates a very important matter. On pages 8 and 9, Mr. Whittaker says, "For transmitting small powers, it may not be necessary to use such a plant, *i.e.*, at 2,000 volts.; but for, say, 500 horsepower to be transmitted one mile, a current of 200 amperes, roughly speaking, would be required, and this would need a cable of about  $\frac{9}{11}$  strand I.W.G., weighing nearly four tons, the double cable, per mile uninsulated, and costing, unlaidd, about £1,000, and there would be a loss of about 90 volts, or  $4\frac{1}{2}$  per cent. in the cable. Using three-phase plant, 500 h.p. could be transmitted one mile by cables of  $\frac{9}{17}\frac{1}{2}$  strand I.W.G., and using the same class of cables, insulated, lead covered and steel armoured, with the pressure at 5,000 volts, the loss would be less than  $2\frac{1}{2}$  per cent.; the copper would weigh  $1\frac{1}{2}$  tons, and the finished cable would cost about £500. These figures are only approximate, but are very nearly correct." Mr. Whittaker's figures here present us with a ratio of one in five. That does not include laying, I think.—[Mr. WHITTAKER: No.]—Well, I find that it costs just about as much to put up an overhead line and to put bare copper on that as it does to bury such a cable as the author describes underground; in each case it costs £100 per mile to do this. It is a very significant fact, and one which the English Board of Trade and Municipal authorities would do well to note, that almost the whole of the lines erected in Europe and America are carried by bare copper wire hung on posts. Unfortunately, in this country, this method of erection is absolutely prohibited, and this restriction is one of the great circumstances which cripple the English electric engineering industry at the present time. The German Government, I may say, favour the erection of overhead wires, and insists on the wire being bare. In England, on the contrary, the Board of Trade, some ten or twelve years ago, passed regulations that no wires were to be erected overhead except the same insulation was guaranteed as in the case of underground wires. The consequence is that the cost of such lines is practically prohibitive, and they are not laid in this country, either overhead or underground. As I have said, this is one of the circumstances which have crippled the native engineering industry. The cost being so enormous no company has been able to lay down lines here, and the illustration I have given is a fine example of government interference with the development of trade and industry. For myself I think the overhead system is even safer than the underground. Turning to the latter portion of Mr. Whittaker's paper, dealing with

lighting—the lighting question was one of the points I most specially went to Switzerland and other parts of the Continent last autumn to investigate. The Directors of the Midland Electric Corporation were anxious to inquire how far, if the three-phase system were adopted for the supply of power in this district for works purposes, it would be feasible to carry out lighting from it. I found certain most important differences existing in the lighting systems on the Continent compared with those which had been adopted in this country. Take for example Wiesbaden, a more fashionable and handsomer town than Leamington, but in other respects much the same sort of town. The lighting installation at Wiesbaden had been carried out by a large company, and it was entirely on the three-phase system. The amount of motive power was not very large, but they were anticipating a very considerable extension of it, while the lighting was very good indeed. At Strasburg the same system prevailed and at a number of other towns also. The experiences of these Continental towns establishes that, on large systems with a circuit of perhaps 3,000 or 4,000 horsepower, the starting and stoppage of power motors, if the mains are of good size, does not affect the lighting of the lamps very seriously. As regards the use of rotary transformers in connection with the two and three-phase current systems, experience shows that as long as the engines have sufficiently good governors to keep them running at the same rate in the central station it does not matter, within very considerable limits, what the pressure may be on the various circuits. A constant pressure will still be maintained on the lighting side for the lamps. This is a very considerable advantage in favour of two and three-phase work and should not be lost sight of by bodies looking about for the best methods for adoption. Mr. Spence spoke just now of having seen direct current instalments working at 15,000 volts. This statement is unquestionably correct; but I think it is not quite a fair comparison because that system is carried out by arranging a number of generators in series. Direct current installations may suit well enough in Switzerland and some other parts, at any rate, for the lighting of the narrow valleys, which are there so numerous, running between mountains where there is a stream in the bottom. But even in these situations, I doubt whether the engineers in charge are to-day so confident as Mr. Spence believes that, as compared with the three-phase system as now developed, direct current is the best form of working which can be desired. In one instance, on my visit I had a long talk with a representative of one of the companies who had laid down most of such plant, and as I have said, I am very doubtful, if measured by to-day's experience, such plants have proved the very best thing. With the present developments, I doubt if the engineers would now altogether recommend them. With reference to the power factor of three-phase motors, I scarcely think the Institute had better go into that subject this evening. It is one which requires very careful consideration in this connection. Still these difficulties are capable of

being controlled, and are not, I consider, sufficient to detract seriously from the very great advantages attaching to the three-phase current. I should like, if the Institute will permit me, to give a few more particulars of the intended work of the Midland Electric Corporation. When I read my paper before the Institute last year on this subject it was impossible for us to say in what part of Staffordshire it was likely the company would operate, since we had not then got very far in our communications with various local authorities. Since then, however, Parliamentary powers have been obtained by the company, and arrangements have been come to with certain of the local authorities which promise very favourably for the company's project. The company have already concluded negotiations for an area comprising a population of about 260,000, and many of the manufacturing localities of South Staffordshire are included. We are still negotiating with some other authorities, so that there is a probability of our area being still further extended. We find, however, that it is extremely difficult to convince the local authorities of the advantages to be derived from our project, or that we can supply power and light to the manufacturers in the various localities at a lower price than the municipalities themselves, all operating with independent plant. The matter is, however, certainly capable of demonstration, and I believe that the favour with which our scheme has been received is growing. It has been a very difficult piece of work to get the town councils and other governing bodies of South Staffordshire to grasp the question at all. Our hardest work is, however, I think at an end.

Mr. J. H. WHITTAKER: The inquiry made by the President concerning the extent to which electricity has been applied to rock drilling work in this country has been replied to by Mr. Spence, and I do not think there is much to be added upon that subject. Concerning the subject of large motors with slip rings raised by Mr. Spence, I very carefully stated in my paper that large motors which were required to start at their maximum load are fitted with three lines for starting purposes only. For tramways and railway purposes, of course, the collectors or brushes are left running on the lines. They are not used at full load, that is at full speed. But they are very different things after all to brushes and commutators—*there can be no sparking*, and there is every chance of getting thorough and efficient installation between the lines. As concerns the running of engineering cranes and separate currents, also referred to by Mr. Spence, if, even with continuous current motors, very heavy cranes are connected to the lighting circuits, and the power demand is in excess of the lighting demand, fluctuation of the light, in quite as marked a degree as with three-phase currents, is sure to result. As regards the objections which have been raised by Mr. Spence to the three-phase system in the matter of lighting, I stated frankly in my paper that the system is not quite so advantageous as the continuous current method, except in cases of an excess of lighting over

power demand, then there is no trouble whatever with the system. With reference to the remarks as to three-phase cranes, I may say I have this year seen many overhead travelling cranes driven through gearing by three-phase motors, also many lengths of shop shafting, where there was most certainly no easing of the belts or fast and loose pulley arrangements.

With regard to the starting of 10 h.p. shunt wound continuous current motors, without resistance, simply by closing a switch, I would say that only the makers of such machines, who can easily repair them, may do this; it will not do in mines, iron or steel works.

The efficiency of a 100 h.p. generator would be about 95 per cent. and not 90 per cent. as stated in the paper.

Coming to the question of high voltage, I am very glad to hear on the authority of Mr. Spence that the continuous current has been run at 3,200 volts. direct from one machine. This is what he tells us the plant, which the Electric Construction Company has supplied to the Manchester Corporation, intended to be used for lighting purposes, will accomplish. I am sorry the circumstances mentioned by Mr. Spence have prevented the plant being tried any length of time, seeing that the work has been turned out by a firm of such repute as the one at Wolverhampton. I have no doubt, however, as to its ultimate success. One of the popular objections to the three-phase system is the necessity for the employment of so many wires. In town lighting on the Continent, however, no difficulty on this score has been found. Lighting with three-phase currents has been successful in this country too, even with the lamps connected to any two wires, a little care being taken as to a balance being obtained; and if four wires have been employed in some cases, the advantages in power plants gained by using three-phase currents have been well worth this small disadvantage. The question has been raised in the discussion with respect to three-phase motor starting. On this point I should like to remark that I have seen three-phase motors driving trains on mountain railways in Switzerland, starting at full load up gradients of 25 per cent. rise, starting perfectly smoothly, without jerk or strain of any kind. Also on tramways and full standard gauge railways, I have seen them start perfectly with very heavy trains. There can be no doubt whatever, in the face of this as to the success of such motors in the matter of starting. Concerning the scheme of the Midland Electric Corporation for Power Distribution, referred to by Mr. Addenbrooke, I should like to ask what the distribution voltage will be under that project, if carried out on the three-phase system.

Mr. G. L. ADDENBROOKE: As to the pressure of the installation we can, of course, use any pressure which may be found most suitable. Our present intention is to so arrange the voltage for a great part of the district that lamps of 200 or 220 volts will be used. This may be

carried out in different ways in different places, and it is possible, if we ultimately obtain powers for the lighting of important towns like Dudley, West Bromwich, and so on, we should put down a three-phase system, connected to continuous currents by means of quota transformers situated in the centre of the town.

Mr. J. H. WHITTAKER: One of the chief points in favour of the three-phase system is its extreme flexibility. In some cases very high voltage may be used and a great economy obtained in wires.

Mr. ADDENBROOKE: On the Continent motors are used as high as 5,000 volts.

Mr. J. H. WHITTAKER: Mr. Addenbrooke, in the course of his very excellent remarks, mentioned several three-phase current plants lately put in operation, or now being laid down in this country, in addition to those named in my paper. It is only fair to say that the plants mentioned by him are very recent. Indeed, some of them, like that for the Central London Underground Railway, are scarcely completed yet. These and other three-current plants which are in embryo in other parts of the Kingdom will come up for treatment in another paper by and bye. In the paper I have submitted to-night, I have preferred to deal with plants which are in actual use in order to give the Institute an idea of their actual working.

Mr. W. BROOKS: I propose a vote of thanks to Mr. Whittaker for his paper this evening. The subject undoubtedly is one which affects all the members of this Institute, or will affect them later on. Assuredly electricity is the power of the future, and as a motive force must largely displace in time steam engines so far as iron and steel works are concerned. In America, especially, the progress which is being made in the adoption of electrical power for driving purposes in place of steam is very rapid, and this displacement is sure to extend, not only in America but at home. Mr. Addenbrooke has given us some additional particulars concerning the scheme of the Midland Electric Corporation for Power Distribution. As to that scheme, for my part, as a member of one of the local bodies myself, I am free to confess that I am now quite in favour of it, and believe it will confer a great benefit upon South Staffordshire. It seems quite feasible that, as Mr. Addenbrooke has remarked, a company with large generating stations may be able to supply power and light at a cheaper rate—indeed, a much cheaper rate—than independent undertakings, the property of individual municipal corporations. Mr. Addenbrooke has, I think, made out so good a case that I quite consider that the trades of South Staffordshire will have cause of complaint against their local authorities if they are deprived of the opportunity of obtaining energy for works purposes from such a Corporation as that of which Mr. Addenbrooke speaks. It is clear that a large central system must lessen management expenses, since one engineer would be sufficient probably for the whole, instead of having

divided management spread over smaller municipal or local undertakings. Another advantage which would be obtained would be the obviating of the cost and objection attaching to the erection and maintenance of generating stations in the different towns. If such stations as proposed by the company are erected in the colliery districts there will be no nuisance to town life.

Mr. J. W. HALL : I have much pleasure in seconding the vote of thanks to Mr. Whittaker. Engineers and iron and steel works' managers like ourselves will, it is clear, have to pay much more attention to the question of electricity in the future than we have hitherto done. It is perfectly certain that the saving which is effected in some of the Continental and American works through the adoption of this power is enormous, and at Messrs. Thomas Richardson and Sons' large engineering works at Hartlepool, which has been mentioned as having recently adopted the system, the saving, I understand, is something like £1,500 per year. The paper and the remarks we have heard this evening from Mr. Spence and Mr. Addenbrooke are of considerable value and will deserve further study. Works' managers will, I have no doubt, be *particularly* glad to hear that three-phase current motors can be got to start easily even with very heavy loads on, and engineers will be only too glad if they can get rid of commutators altogether, as they are the chief cause of trouble with electrical plant when used for power purposes.

Mr. G. L. ADDENBROOKE, in supporting the vote of thanks, said : The Institute will probably be pleased to hear that the promoters of the Midland Electric Corporation have come to the conclusion to lay down first a 5,000 h.p. station. I think I made it clear in my paper, last year, that the company proposed to charge on a sort of sliding scale for the current—that is, that the price would vary according to the use. Of course the main cost will be the capital expense of putting up the plant, and such charges will have to be made as will pay the company interest and depreciation on the original capital outlay. The extent of the demand for the new power will also be a very important item in deciding the question of price. Supposing the ordinary load was 5,000 h.p., and a demand arose from any one customer for 500 h.p. more, and that he required this additional amount at a time when the station was already running at its full load, it is clear that the company would have to put down more plant, and that the expense of supplying that additional 500 h.p. would be very considerable. Again, suppose the additional power was required for lighting and not for machine motive purposes, and was needed we will say not more than three hours per day, the charge made for such extra power would have to be still higher. The circumstance that power for lighting would be required by manufacturers so many fewer hours per day than motive power would necessarily render the cost for lighting considerably dearer than that for motive purposes. For that reason the average cost of the current for lighting is estimated by

the company at present at about 4d. per unit. The Institute will at once be aware, without my dwelling upon the fact, that this is a very low price—indeed, it is about as low as is charged, I think, anywhere in the Kingdom. Another reason which makes the light more costly than power is that there will only be very little demand for it in summer from manufacturers. With power on the other hand the situation is quite the reverse. Works go on pretty nearly equally all the year round, and there is a fairly regular use of the current of, perhaps, 10, 12, and in some cases 24 hours per day. Different sets of rates of charges, therefore, will apply to power and lighting. In an ordinary plant running in an ordinary engineering works, I think the cost for power will come out on the average at between 1½d. and 1¾d. per unit; the exact price depending very largely upon the character of the load. Mining pumping, such as is carried on by the South Staffordshire Drainage Commissioners for example, or by private colliery owners—this of course goes on the whole 24 hours round, and the charge for this purpose will necessarily be lower still. The cost to users under this head will be less than 1d. per unit, and if the Mines Drainage Commissioners, or any private colliery owner, are prepared to make an arrangement with the company that the pumping of water may be cut off for two hours out of the 24 and the water allowed to accumulate in the sump—not a very serious circumstance—the company would be prepared to make a reduction on the 1d. per unit charge, and the work could be done for perhaps even ¾d. per unit.

The vote to Mr. Whittaker having been carried with acclamation, the Author, in reply, said that if he had been able in his paper to help the members of the Institute to a better understanding of the three-phase current system, or had done anything to advance the matter of electric power distribution in South Staffordshire, he had been amply repaid.

The sixth Meeting of the Session was held at The Institute. Dudley, on Saturday, March 25th, 1899.

THE PRESIDENT occupied the chair.

The minutes of the previous meeting were read, adopted, and signed.

Mr. Alexander Josiah Baker was elected a member of the Institute.

Proposed by Mr. W. BROOKS, seconded by Mr. JAMES FISHER, and carried—that Messrs. Walter W. Pagett and William Whitworth be appointed Auditors of the Institute Accounts for the year ending 31st December last.

Mr. JENNER G. MARSHALL then read the following paper :—

## MEANS OF TRANSPORT IN AND ABOUT WORKS.

By JENNIE S. MARSEALL, Assoc. M. Inst. C.E., A.M.I.E.

This subject is one which is not only likely to interest us individually, but which must affect in a marked degree the industrial prosperity of any country. It is, therefore, well worth careful study.

I propose to divide the means of transport into two main divisions, *Fixed* and *Movable*, and to sub-divide these again, as follows:—

*Fixed*, into canal and dock basins, railways, cranes, elevators, conveyors, chutes, and rope haulage.

*Movable*, into carts, rollers, sliding skids, and ways and rollers; and in connection with these, winches, driers and tackle worked by hand or horses; and traction engines; though, of course, the time at our disposal is hardly sufficient to do more than mention these sub-divisions, and to give a very few details connected with them.

They are often dependent on each other for maximum efficiency:—

### FIXED MEANS OF TRANSPORT.

Canal and dock basins are used mostly as means for delivering goods to and receiving them from works. Some appliances for making this possible are described further on. Branches from main lines of railway not only in as much of this direction as canal branches, but are used to a large extent for moving materials about from one part of works to another.

Sometimes these lines are without help from narrow-gauge railways, at other times works are supplied with narrow-gauge lines as well; and in one worst case built on the most carefully-thought-out lines, viz., Messrs. Wilson and Johnson's at Rugby, there are no less than three gauges used. The standard, 4 ft. 8½ in., with two other rails fastened to the same sleepers, so as to form lines of about 3 ft. 6 in. gauge and of about 4 ft. 6 in. gauge. Neither the 4 ft. 8½ in. nor the 3 ft. 6 in. gauges go all over the works, but the 4 ft. 6 in. gauge goes almost everywhere. These three gauges are found a great convenience, as the size of truck can be proportioned to the work to be done, and the hands available to do it.

### WOOLWICH ARSENAL SHOP RAILWAYS.

This railway serves to connect 400 acres of shops, storehouses, etc., and has a length of about 3 miles; 30 being of 3 ft. 6 in. gauge, and the remainder of 4 ft. 8½ in. and 4 ft. 6 in. combined.

There are 36 locomotives of 18in. gauge, nine of 4ft. 8½in., and a special Hornsby-Akroyd oil locomotive.

The rolling stock consists of 1,000 vehicles, two-thirds of which are for the 18in. gauge, and the remainder for the 4ft. 8½in.

The whole system is divided up into six sections, with a complete service of trains, telephonic communication, traffic manager's office, and necessary staff.

A truck can be supplied to any shop, loaded there, taken to the junction on the works main line, and then conveyed by the main line to any other section and so to its destination in one hour from the time of its requisition.

The number of trucks passing daily over the main narrow-gauge line, averages 400, or say 2,000 tons, exclusive of any special coal traffic, and of the shifting of material inside the shops themselves.

There is a passenger train running round regularly every half-hour on the narrow-gauge main line, with stoppages at quarter-mile intervals.

#### GUINNESS' BREWERY IN DUBLIN.

An exceedingly efficient system of 22in. steam tramway was designed and built in these works some years ago by their engineer, Mr. Geoghegan.

The two special features are the Spiral Tunnel and the Haulage Truck.

#### SPIRAL TUNNEL.

The 50ft. difference in level between the old and the newer part of the works was first got over by means of a hydraulic lift. This was a very slow and costly process, involving the separation and making up again of the trains. Instead, the line was made continuous, by means of a Spiral Tunnel of 61ft. 3in. radius, with 2.65 turns, and a gradient of 1 in 40. The height is 7ft. 3in. from the rails, and the width 8ft. 9in. By means of this tunnel an immense saving was made both in time and money.

#### HAULAGE TRUCK.

The mode of using this ingenious apparatus is as follows: The 22in. gauge engine is lifted by hydraulic power upon a broad gauge (*i.e.* 5ft. 3in.) haulage truck, having four grooved wheels on which the wheels of the engine rest, with their flanges in the grooves; and on the counter-shafts carrying these wheels are pinions, gearing into spur wheels on the axles of the truck-carrying wheels. The weight of the truck is between eight and nine tons, making with the engine about 16 tons. The haulage power of this combined apparatus is about double the haulage power of the engine alone. It has to haul four broad-gauge wagons (5ft. 3in.), each weighing about 12 tons, up an incline of 1 in 70, with curves of 50 and 70 feet radius.

**SIR PERCIVAL HEYWOOD'S SYSTEM OF RADIATING LOCOMOTIVE WHEELS.**

This is a most ingenious invention and well worth the consideration of anyone laying down railways with very sharp curves.

The wheels, of cast steel, are not fixed upon the axles, but each pair is keyed upon a cast-iron sleeve, through which the axle passes—the sleeve upon the middle axle is capable of sliding one inch in each direction laterally, but cannot revolve upon its axle; thus when the engine reaches a curve, the arc of the rail draws the middle wheels on their sleeve to an amount equal to the versed sine of the arc, without interfering with the rigid position of the axle.

The leading and trailing pairs are likewise mounted on sleeves, but here the connection of the sleeve with the axle is by means of a ball-joint at the centre, so constructed as to leave the sleeve free to radiate in any direction, but obliging it to revolve with the axle. The middle sleeve is so connected by external hoops and links with the leading and trailing sleeves that, when the former makes a lateral diversion, the two latter are radiated precisely to the required curve, providing it is within the limit of the travel of the middle sleeve, which, in this case, is arranged for a radius of 25 feet.

Besides lines of railway laid more or less on the ground-level, in manufacturing works the system of overhead railways, in which the railway runs at such an elevation as to be able to tip the material where used, has done, and is doing, good service.

The trains or single trucks are either brought directly into the works at the required level, or if the level of the ground prohibits this, they are raised to the required level by hydraulic power or otherwise.

These slides represent the Caen, Dives, and Luc Railway, constructed by the noted Decauville Co., and lent to us by Mr. Leslie Robertson. Although this railway is not in works, I think that these photos of a 60 c/m line may interest you.

**CRANES.**

Cranes can be divided into those which move bodily with their load from place to place, and those which simply raise their load and turn round their own axis with the load.

Among the first belong the *travellers*, moving on rails placed on a high level so as to enable them to raise and carry their loads free of obstruction. The movement of their load is across and along a rectangular space and vertically. They are thus enabled to serve any part of a shop or store. In many cases several shops, etc., are placed side by side, each has its traveller, worked by hand, rope, square shafting, independent engine and boiler, or by electricity, driving motors, carried on the traveller itself.

Through such a number of parallel shops a road and a railway run at right angles to their individual lengths.

A load can thus be raised in any part of any shop, carried to the railway, run into any other shop, and there lifted by the traveller and placed where required.

Akin to the traveller is the *Goliath*, used where walls or other supports do not exist for carrying the travelling wheels at a high level.

The rails are laid on the ground, on these gauged wheels run and support long columns or legs to which the cross beams are built, the hoisting mechanism being thus placed at a high level. They are used very largely in stone and timber yards, and in handling cement blocks used in pier and dock making.

#### COAL HOISTS.

The fixed crane, which, I suppose, does more work in 24 hours per ton of its own weight than any other, is that used for hoisting coal out of vessels.

The general mode of working, is that a large iron tub is lowered (by means of a hydraulic or steam jib crane of special construction) into the hold of a vessel, where it is fitted by hand, is raised and weighed, and then emptied, either into a barge or elsewhere. By this means, large steam colliers can be emptied in a very few hours.

Some of these coal hoists are fitted with a grab. The Gas-light and Coke Company have some at work, made by the Thames Ironworks, which can unload between 60 and 80 tons an hour, lifting the coal above 50 feet.

#### LOCOMOTIVE CRANES.

Locomotive cranes, that is, cranes formed of a carriage running on rails with a jib crane, or its equivalent supported on it, are very useful tools.

Their part is to do work within a short distance of a permanent line of rails, either of standard or other gauge.

They are worked by hand or power. In the case of steam being used, they can lift, turn, or travel by power. They carry their own boiler, which *should* be of ample size, and very often is not, and can of course travel as far as the line extends.

Locomotive cranes worked by hand, and of small power, are frequently moved along the rails by shoving, without their travelling wheels being gear driven. It is a very good practice to have the travelling wheels fitted with rollers.

In one case, by fitting the wheels with rollers, I found that a boy could easily move a crane, which before had been really hard work for two men.

### ELEVATORS AND SCREW CONVEYORS.

Screw conveyors may be sub-divided into spiral or paddle, both of which are really a development of the Archimedian screw, their action on the material being very much the same as a screw on its nut, or of a steamship propeller on the surrounding water.

They are used for moving large quantities of slack, corn, slurry, sand, and the like, either in a dry or wet condition, to a comparatively short distance.

The diagram you see here represents a conveyor-bearing, which I patented some years ago. It is worth mentioning as it made a great success of what would otherwise have been a failure.

The conveyor (which is still daily doing good work) carries wet sand. The original bearings were cut straight through in a few hours.

My bearing, as you see, consists of an ordinary long rocking bearing, supported in a convenient bracket, which can be taken adrift, so as to renew the cast-iron brasses, without unshipping any other part of the conveyor.

The sand is perfectly prevented from entering the bearing by the simple expedient of a canvas sleeve, which you see painted red, and which is secured respectively to the conveyor shaft on one side, and to the bearing on the other, by means of clips as shown.

The shaft is formed of a tube, so as to enable the number of bearings to be reduced to a minimum.

Some chief points which I have noticed in screw conveyors are, that you should have large bearing surfaces, few bearings, as little affected as possible by their being out of line; and the conveyors should not be allowed to stop so that the material can settle down and embed the conveyor.

The material should always be kept moving and lively.

The conveyor is often fed by an elevator, consisting of a chain and buckets collecting the material to be conveyed in a boot or pit, into which the material is first thrown.

### THE SWINGING CONVEYOR.

The swinging conveyor consists of an open trough, fixed on inclined springs either on the floor or suspended from the ceiling. The trough is set into a shaking motion by means of a small countershaft and crank.

The material, which is deposited into one end of the trough, travels with great rapidity, and yet in a gentle floating manner to the other end.

The trough going forward carries the material with it when the conveyor suddenly comes to a standstill, and withdraws backwards and slightly downwards, and this process repeats itself with every stroke.

### TEMPERLEY CONVEYOR.

The Temperley conveyor consists of a carriage moving along a beam or boom. It is worked by a rope for lifting and travelling, and has a special block.

The beam is either supported in a fixed position as in a warehouse, or is supported by its centre to a travelling tower, so as to move along a quay, etc., for emptying vessels.

If the carriage moves along a boom, the boom is hinged to a fixed mast at one end, and supported by ropes along its length. A boom will cover half a circle. The others cover a rectangular space. The carriage moves in one direction by being pulled by the rope. If the beam is horizontal, the carriage must be pulled back, if inclined, the carriage will return by gravity.

The mechanism is so arranged, that the rope which lifts the load, pulls the carriage to the desired position, after the load has been lifted.

The *diagrams* show examples of the general types.

### BANDS.

Bands running at about 600ft. per minute, are used very extensively as conveyors in wheat stores and corn mills. The wheat is delivered onto the canvas or rubber band from a shoot and carried to the part of the premises where it is required. Very often one band cannot reach its ultimate destination, and the wheat is then delivered from one band to another until the required object is obtained.

The wheat is either scraped off the band by a kind of plough, or is thrown off by its own momentum. If required to be removed at the end of the band, of course it will fly off into a hopper without any intermediate apparatus. For delivery at any other point by momentum, a throwing-off carriage is used, shown by the *diagram* before you.

Band conveyors are used for conveying coal and the like, but in this case have supporting rollers which give a certain amount of hollow to the surface of the band, making it in fact a travelling trough.

The creeper or tray conveyor consists practically of a slow moving band, made of overlapping plates fastened to special chains. This apparatus is a most convenient one for emptying coal boats. The boat lies parallel to and alongside the creeper. As many men as can work in the boat, can then shovel the coal onto the creeper which delivers it at its end into a pit from which a bucket elevator carries it up to other conveyors, coal screens, etc.

Instead of this tray conveyor, the push plate conveyor can be used. This is an endless chain with scrapers fixed at right angles to the direction of motion. These scrapers push the material along a trough at any point of which it can be delivered through an opening in the bottom.

### CAPSTANS.

Capstans are much used in railway yards, and consist in vertical revolving drums set in motion usually by a 3-cylinder hydraulic motor. The way of using them is as follows: One end of a rope is made fast to a railway wagon and a couple of turns taken round a capstan in the desired direction. When the wagon has been sufficiently moved, the rope is slacked off and the motor stopped by simply stepping on a button provided for that purpose.

### ROPE HAULAGE.

Haulage rolling stock on rails by means of a rope moving parallel to the rails is a very old system in this district where full colliery tubs draw empty tubs to the pit's mouth for re-filling.

The rope has, however, a good many capabilities. It can be set in motion by various means. One of the simplest is the case of some mountain railways, where there are two trains on one rope, each having a large water tank. The tank is filled with water at the top, and by descending hauls the lower train with its empty tank to the top of the mountain.

This system can be adopted either for vertical or inclined lifts, wherever there is an abundant supply of water at the top level.

The diagram shows rope haulage applied in quite a different way, viz., to raise a vessel out of the water on to dry land, so as to overhaul and repair her.

This is Messrs. Wm. Cory and Sons' Slipway, at Erith, designed by Mr. Harry Shoosmith, Assoc.M.Inst.C.E., for repairing tugs.

The cradle is lowered outwards and downwards to its extreme extent in the water, the vessel is then towed or steamed over it until the stem of the vessel touches a projecting upright V shaped post, very strongly stayed; it is lashed to this, and then pulled directly over the blocks by guide-irons, which hinge to the truck. When all is ready, the truck is hauled up, bringing the vessel with it, until it grounds on the truck, and is brought out of the water on the top of it. The blocks underneath are then made quite secure. The advantage over a dry dock is, that vessels can be hauled on and off at about half-tide, thus saving several hours. If rails were long enough it is possible to lift a vessel dry irrespective of the tides.

### MOVABLE MEANS OF TRANSPORT.

#### TIMBER SKIDS.

Passing over carts and trolleys as being familiar objects, and not likely to be much improved, I should like to impress on you the great use which can occasionally be made of timber skids running on well-soaped timber ways.

The weight, which can be supported and easily moved, is very great, and the skids can be placed under irregularly-shaped loads without much difficulty, as a rule.

I have before now moved a marine engine, weighing some tons, from its erecting shop to the shear legs in one piece, in this way, and then lifted and lowered it on to the engine framing, thus saving the time of dismantling and re-erecting.

For moving heavy weights in this way, and also on rollers, a good anchorage is required, more or less in the direction that the weight has to be moved. Between this and the load tackle is fixed and the fall hauled on by a winch, or by hand, or by a horse or two—horses give excellent results in this way if active, quiet, and handy.

#### TRACTION ENGINES.

And now we come to the last material-moving tool I propose to mention, viz., the portable engine. This is exceedingly useful in a boiler or ship yard and the like, being able to move about independently of rails or even roads, and to draw carts of one kind and another wherever it can get itself.

A most useful addition to the ordinary traction engine is a gib crane fitted in front of the smoke-box. Messrs. Aveling and Porter's four-ton Road Locomotive Slewing Crane is, I suppose, very near perfection.

Besides fulfilling the functions of an ordinary traction engine it has a crane attached for lifting and carrying heavy weights.

The crane can slew at right angles to the axis of the boiler. It can be employed with much economy in loading and unloading lighters and wagons on wharves and at railway stations and in many other kinds of work.

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THE PRESIDENT intimated that he had three slides he should like to exhibit to the Institute in illustration of the subject of Mr. Marshall's paper. Mr. Tucker had consented to put them under the lantern.

The President's slides were as follows:—

No. 1.—A crane made by Messrs. Booth, having three separate cylinders, one for slueing, one for travelling, and a third for lifting. A very similar crane was, the President explained, in operation at the Earl of Dudley's Round Oak Iron and Steel Works.

No. 2.—A charging apparatus for steel works use, for charging ingots or slabs into the reheating furnaces. This appliance was also the manufacture of Messrs. Booth. The President added that one was to be found working at the Cwmfeln Steel Works, and the Bryngwryn Steel Company, Gorseinon, Swansea.

No. 3.—A travelling crane, also for steel works purposes. Its object was the raising of ingots out of vertical furnaces or soaking pits and placing them on to a table so as to reverse the motion of the ingots and deposit them for travelling on the live rollers fitted in the works floor. This crane was also manufactured by Messrs. Booth, but the President explained that he was not informed where it was actually being employed. That, however, could be doubtless easily ascertained if any member of the Institute desired the information.

The President said that the three slides he had shown would probably have been of interest as specimens of up-to-date mechanical appliances, designed for the handling and transporting of iron and steel work quickly, economically and efficiently.

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## THE DISCUSSION.

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THE PRESIDENT: I have a telegram this evening from Mr. Silvester, our vice-president, who regrets his inability to be present owing to the state of his health; and Mr. Hall, our past president, is also unable to be here owing to the same cause. There is no subject which is more likely to interest the members of this Institute than the subject of the paper which has been read this evening. As a matter affecting the economy of every day conduct and practice it should receive every consideration at our hands. The field covered by the author is an exceedingly wide one, with which it would be impossible to deal adequately in the space of a single paper. It is not surprising, therefore, that it should be very easy for us to mention very many classes of machinery, in addition to those specified, as capable of contributing in an important degree to economy and reduction of cost of manufacture.

One of the last modern inventions which is being found of great value in some centres is the pig-casting machine. This appliance has been adopted, to some extent, in the North of England, and by its means the owners of those plants where the invention has been laid down are believed to be able to make a saving of something like 2d. per ton on the output. Then we may mention the pig breaking machine. This invention is in operation in Wales, particularly at the Dowlais Ironworks, and there is also one at the Cleator Ironworks, Cumberland. This last machine was designed by Mr. Croasdeil. The operation of the appliance is that the pigs are taken direct from the casting beds by means of overhead cranes to the breaker, and from this latter they fall direct into railway wagons ready for taking away. Here again I understand the saving is about 1d. per ton. Those individual items of economy may not seem very large, but when it is remembered that 2d. per ton saved on the total pig iron produced in this country during last year would

mean a saving of £70,000, the Institute will at once see that these small items are in the aggregate of considerable importance. The steel ingot charging apparatus which I displayed on the screen just now, made by Messrs. Booth, now in operation at Swansea, and a duplicate of which is to be laid down at Middlesbrough, means the saving of the labour of a number of bogie men when charging reheating furnaces, and machinery of this class is especially welcome, since this labour is always a standing nuisance. The men are continually striking or creating some other difficulties, and a reduction of the number of hands is therefore very gratifying. At the Hartlepool Steel Works, I put down one of these ingot-charging apparatuses which was a copy of one I had seen at Leeds, and there was a similar one also working at the Barrow Steel Company's works. The result of the laying down of the machine at Hartlepool was a great saving in labour, and during the three years I was there it did not cost a penny in repairs. When I was general manager of the Round Oak Steel Works of the Earl of Dudley, I designed a similar machine, which was manufactured by the Lowca Engineering Company, Whitehaven, and which I hear has been in operation continually ever since and doing excellent work. Live roller gearing in iron and steel works has not been mentioned by the author, but we all know what a constant saving of labour this class of mechanical transport means. In fact, but for this invention there is no doubt that some of our works would not be able to live at all, so very considerable is the economy appertaining to its employment. Another labour-saving machine which cannot be passed over in silence is the tipping gear for tipping and placing blooms in front of the blooming mills. An important portion of Mr. Marshall's paper was that dealing with tramways about works. Mr. Marshall mentioned that at Messrs. Willans and Robinson's works, at Rugby, which he describes as "works lately built on the most carefully thought-out lines," there are no fewer than three gauges of tramway used. Now with all due respect to the designers of Messrs. Willans and Robinson's works, whoever they may be, I think, speaking from practical experience, that the fewer the number of gauges laid down at any one works the better. If it is possible to so arrange works as to confine the whole system to one gauge so much the better, but in no case, unless there are special difficulties which cannot be got over, should two be exceeded. Unfortunately, in our Porthywaen Lime Works, at Llyncllys, near Oswestry, we have six gauges to contend with, namely, 20in., 22in., 24in., 36in., 4ft., and the ordinary 4ft. 8½in. railway gauge. Of course, however, the works have been extended at various times, and on different occasions, and this accounts for this manifold confusion of sizes. The Institute can well understand how extremely inconvenient the present complicated system is, and what a great loss in labour is thereby entailed in the transport of material from one gauge to another. I am doing my best to bring about a different state of things and get the matter altered, and I hope I shall ultimately succeed in getting the whole re-arranged

on a two gauge basis ; but of course this will be a matter of time, and a great expense will be involved in converting the railway stock. A celebrated gauge which Mr. Marshall has not mentioned in his paper is that which is just now coming to the front in connection with the proposition to lay down a new lightning railway line between Manchester and Liverpool. This is the system known as the Mono-railway, invented by Mr. Behr, upon which principle a line is already laid down in Belgium, and also one in Ireland. Whether there is a future for this rapid system of conveyance, which proposes to travel at the rate of more than 180 miles per hour, and which would mean covering the distance between Manchester and Liverpool in 15 minutes, and between London and Birmingham in 45 minutes, it is too early as yet to pronounce ; but there are features about it which will recommend it to further experiment, and we are certain to hear more about it. There is one matter I should like to ventilate this evening to which I think the Institute, as Managers of Iron and Steel Works, both raw and manufactured, would do well to give immediate attention. This is the question of the automatic unloading of railway trucks and wagons. At present there is an immense amount of time and labour wasted in this operation, and the need for early reform is a crying one. The blast furnace owners of Staffordshire in particular would, I think, find it to their interest to employ self-unloading trucks so that the contents may be tipped out into the bunkers with the minimum amount of labour. Speaking of railway trucks reminds me that a considerable saving may be indirectly effected at many of the Staffordshire works, if the management would pay more attention to the requests of the railway carriers for prompt unloading on arrival at sidings. The members of the Institute may not be aware of it, but it is none the less an actual fact that consumers themselves have to pay for the present delay in this matter of unloading. When the trucks are delayed at any works more has to be paid for the hire of them and for carriage of goods. At the Porthywaen Works we have a system of recording the time that is taken by our various customers in unloading the wagons, and we know exactly which of our customers keeps the trucks the longest and which the shortest. Very frequently in making contracts afterwards, whether the trucks will be kept waiting about on sidings, is a consideration in the price quoted. There are many other firms who work on exactly the same principles as ourselves in this matter, and you will, therefore, see that the subject is one well worth your consideration. Wire roads or ærial tramways are another means of truck transport which has not been mentioned by Mr. Marshall, probably because they are not very much in evidence in many of our works. Still where they exist they are very useful for conveying materials over long distances, and we are now putting up such an ærial line at our lime works, and we anticipate we shall find it an appreciable source of economy. In conclusion a word should be devoted to the economies effected by cranes of the Cantiliver, Sampson, and Goliath

types, to say nothing about the Annanias's produced by our foreign competitors. As supplementary to the figures I mentioned just now in relation to the aggregate saving which would result from an affecting of even small economies like 2d. per ton on the annual output of pig iron in this country, I may say too that an economy of only 1d. per ton upon the quantity of limestone quarried last year would mean a saving of £50,000, and the same economy applied to the coal output of the Kingdom would represent a lessened cost of from £800,000 to £1,000,000.

MR. WILLIAM BROOKS: The communication of this evening should be of much practical value, because most of our members are connected either with iron or steel works, for other heavy manufactures of this district, and the systems employed in conveying and moving materials about must always be of importance. The question has been asked how it is that in Staffordshire many of our works are destitute of the most economical mechanical systems of conveyance and handling. Many of the works were laid down a long while ago, and it would be far better at many of the works to pull them right down and clear the ground and rebuild and reequip them, rather than interfere with existing arrangements. This does not, however, lessen our indebtedness to Mr. Marshall for his paper this evening. There can be no doubt that very great economies would be effected in the manufacturing processes of the Staffordshire district if new works were laid down and equipped with the most modern mechanical methods for superceding the present very extravagant, over abundant employment of hand labour. Any district, or any works, reequipped would be in a far better position to compete with other districts and also with other countries than old plants. The surprising examples we have had in our own country, as well as on the Continent and in America, of late years of the economy which may be effected by employing up-to-date machines in every department, affords abundant proof, if any were needed, of the position I have stated.

MR. RICHARD EDWARDS: While thanking the author for his excellent paper, I think he would have done well if he had adapted his remarks to our everyday works experience rather than have travelled over so miscellaneous a field. The subject of works economies by the substitution of mechanical for hand labour is a very attractive and serious one, and will undoubtedly repay over and over again the closest attention it is possible to give to it. Much progress, as already suggested, has been accomplished in America and on the Continent in this direction. Indeed the acute pitch to which international competition in iron and steel manufacture, and many other industries likewise, is growing, compels invention of this sort, and also the adoption of inventions if business is to be carried on. The President's remarks concerning the saving which might be annually effected in our pig iron, coal, and limestone production by the increased adoption of mechanical transport and service are exceedingly timely, and the figures which he has adduced

may well inspire further progress in the subject which Mr. Marshall has brought before us.

MR. R. W. BRADLEY: Can Mr. Marshall give us any information about any system of automatic unloading of canal boats? The cost of loading and unloading is one of the most serious items of expense we have to meet at the ironworks in this district, and any information the author can give us concerning any mechanical means for solving this problem we shall be deeply grateful for. At our works we have during the last two weeks lost between 500 and 600 tons per week of stock for want of sufficient boat unloaders to get through the unloading with the same regularity as the carters do, and I am perfectly certain that our experience is by no means singular.

MR. JENNER G. MARSHALL, in replying on the discussion: I do not think there is very much which I need reply to this evening, but I should like to refer casually to one or two points. Mr. Brooks has remarked upon the much greater alacrity with which iron and steel masters on the Continent and in America reconstruct their works than they do in this country when the mechanical processes employed have become out of date, or, from any other cause, less economical than might be employed. I am not an ironmaker myself; but there can be no question as to the correctness of Mr. Brooks's statement. If on the Continent or in America, especially in the latter country, an iron or engineering works becomes old and out of date in respect to its plant, it is immediately knocked down and rebuilt, instead of attempts being made to patch it up, with the result that the proprietors instantly begin to save money by their increased output, and largely reduce their cost of running. This example is one of the most glaring instances in which English manufacturers lag behind their United States and European competitors, and yet they are always talking about the severity of foreign competition. I cannot conceive any policy more likely to result in the inability of our home firms to meet the foreigner in the matter of selling prices than this too often fatal system of unwillingness or inability to part with old machinery—a perversity, which is, perhaps, traceably in some cases to insufficient recognition on the part of our own firms of the importance of this works' equipment problem. The Institute will, I feel sure, bear me out when I say that engineers and managers in this country have often the greatest possible difficulty in persuading works owners to substitute up-to-date methods of working, for such as perhaps have been in use for many years after they are superannuated. Very frequently, unless an increased profit of 20 or 30 per cent. can be shown on the outlay before the alterations are begun, a deaf ear is turned to all appeals for reform; and how seriously these conditions interfere with progress it is very easy to see. In the United States this is not so. There is no waiting there for a heavily increased profit to be absolutely demonstrated before alterations are commenced. American manufacturers seem to have sufficient faith in the fully accredited engineering and industrial

formula, that "lessened cost of output must necessarily mean increased ability to compete at low prices, and increased chances of enlarged profits," to undertake reconstructions quickly and heartily. The result is, as we see to-day, that they are leading everywhere in the matter of the prices they can afford to accept for their iron and steel and engineering products, so that their ability to execute large orders from abroad as well as at home, on the shortest notice, is greatly enhanced. The illustrations that we have lately had of this situation in this country in the matter of locomotive contracts, bridge building, and other work, convey ample conviction upon this point. Mr. Bradley mentioned the question of transporters for the unloading of canal boats, and enquired whether I could give him any information upon the matter. I regret that this evening we have not time to go into the case of such mechanical appliances; but of course such a system of boat emptying is perfectly feasible for the works in the South Staffordshire district, and I should think would result in marked economy in almost every case. If the Institute would care to have it, I should be very pleased to lay before them some information on the subject at some future time. The transporter which was thrown on the sheet just now is in operation at Messrs. Williams's Lime Works, and I expect the firm would be quite willing for an inspection of it to be made.

MR. R. W. BRADLEY: Judging from the slide, Messrs. Williams's transporter seems to be very conveniently situated for their particular class of work, but you must understand that the situation of a canal boat would be very different to that. The loading which Messrs. Williams are doing at their works even with the transporter must cost them more than it would for the loading of an ordinary canal boat on the level, their situation being so much higher than ordinary boat unloading. I am sure there is a very good opening in this district for a mechanical means of boat handling at our ironworks and blast furnaces.

MR. JENNER G. MARSHALL: The appliance at Messrs. Williams's Lime Works is a very handy arrangement, and comparatively new in this district. One old and tried plant for canal boat unloading such as has been mentioned is the scraper conveyor. Six men can be arranged to shovel from the boat on to the creeper at one time, so that the Institute will easily realise how quickly unloading can be got through. This, of course, is only one of the many appliances for unloading. Special requirements can practically always be met, and material unloaded from boats or trucks and deposited at any distance and to any depth required in an economical manner. Before I sit down I should like to thank the meeting for the kind way in which they have received my paper, and I also have to take this opportunity of expressing my thanks to those who have lent me slides and diagrams to illustrate it. Especially is my gratitude due to Mr. Tucker for the great trouble he has gone to in making slides for illustrating the paper, and for showing them here this evening.

Mr. A. E. TUCKER : I am sure there was no occasion for Mr. Marshall to have mentioned the matter of my services this evening in supplying slides for illustrating the paper, for having asked him to give the paper, I felt under some obligation to assist him. At the same time I must thank him for the manner in which he has referred to the work. I have to propose a vote of thanks to the author, and I do so with great pleasure. While fully appreciating the labour which Mr. Marshall has been to in getting together the descriptions of such an accumulation of mechanical means of transport in and about works, it will be apparent to most of us that he might perhaps have adapted his paper a little more to the specific requirements of the iron and steel works. In dealing so broadly as he has done with the general question—a feature in the paper which of course has much merit—he has left himself little room to particularise the special apparatuses which must be of daily service in iron and steel works practice. Before putting the resolution, I may perhaps mention one method of rapid and economical transport was adopted in connection with the trans-channel passenger steamship service which effects a very great saving of time and labour. I refer to the extremely effective system which has been introduced during the last few years for dealing with passengers' luggage. This, as everyone knows, is of a very heterogeneous character, and instead of, as formerly, being cast loosely down shoots, or into railway vans, the whole luggage is now boxed in large receptacles intended for the few termini and placed on the railway, where it is directly conveyed to the boats and so to London, or *vice versa*. In this way, by the use of power cranes, the handling is done in a fraction of the time. It occurs to me that the principle of this rapid and cheap method of handling might be applicable to some of the materials which ironmasters have to deal with, and in this case the system, perhaps, as exemplified to some extent by the similar system adopted by the Cheap Fuel Company, of Wolverhampton, is worth your attention. The principle underlying the system is, of course, that subdivided and taxed material can be much more conveniently dealt than when such material is in the loose state. I have much pleasure in proposing the vote of thanks due to Mr. Marshall.

Mr. RICHARD EDWARDS seconded the vote of thanks, and Mr. WILLIAM BROOKS, in supporting, said that if the author would invent mechanical apparatus such as Mr. Bradley had referred to, it would unquestionably be very acceptable to the South Staffordshire district. Everyone must recognise that the cheaper this boat handling could be accomplished the better for the whole industries of the district.

Mr. MARSHALL : It has given me much pleasure to prepare the paper for pre-entation to you this evening, and I have to thank you for your vote of thanks. Of course it was not intended to be in any way an exhaustive paper, nor did I desire from the outset to confine myself exclusively to iron and steel works practice. One could sit down and

write for a very long time without anything like exhausting the subject we have been considering this evening, if one entered into anything like detail upon the various matters treated. I only designed that my paper should be a sort of summary which might be suggestive to some of the members, and likely to produce a good discussion. As the time for reading and discussion was so limited, I concluded it was unwise to attempt to go at all deeply into the many details of the subject.

## ANNUAL MEETING.

The Annual Meeting was held at the Station Hotel, Dudley, on Saturday, April 29th, 1899. The retiring President of the Institute (Mr. LE NEVE FOSTER) presided during the first part of the proceedings; after which the chair was vacated in favour of the newly-elected President, Mr. H. SILVESTER.

The minutes of the last meeting were read, adopted, and signed.

Messrs. Michael Devitt, Herbert Hammond, and Samuel Whitmore were elected members of the Institute.

The Annual Report of the Council and Audited Balance Sheet for year ending 31st December, 1898, were then read by the Secretary, as follows :—

### REPORT OF COUNCIL FOR SESSION, 1898—99.

The Annual Excursion took place on the 22nd June, 1898, when 238 members and friends visited Portsmouth Dockyard.

Six Ordinary Meetings have been held during the year, at which the following papers have been read :—

10th December, 1898. "The Blast Furnace as a Source of Power," by Mr. Horace Allen.

7th January, 1899. Presidential Address, by Mr. H. Le Neve Foster, President.

11th February, 1899. Chilled Rolls, and Why they Break," by Mr. E. D. Nicholson.

11th March, 1899. "The Measurement of High Temperatures," by Mr. T. H. Waller.

18th March, 1899. "Electricity in Mines and Ironworks, with Special Reference to Three-phase Currents and Motors for Power Transmission," by Mr. J. H. Whittaker.

25th March, 1899. Transport in and about Works," by Mr. Jenner G. Marshall.

Most of the papers were copiously illustrated by diagrams and lantern views, and two of them by experiments and models.

The meetings have been well attended, and the subjects dealt with in the papers have been well discussed.

During the year the following have joined as members :—

*Honorary*: Messrs. Walter Jones and J. Knowles.

*Ordinary*: Messrs. W. J. Foster, Jno. Harley, W. H. Richards, G. W. Summers, J. H. Whittaker, G. A. Millward, W. W. Attwood, A. J. Baker, Jno. Bate, R. W. Bradley, Geo. Higgs, W. Nock, Jun., and W. H. Venables.

The following have left during the year:—

*Honorary*: Messrs. S. Dickinson and Sons and Jno. Glaze.

*Ordinary*: E. Cookson, Rd. Lowndes, A. McWilliam, S. Wilkinson, Jas. Bunch, J. Crofts, F. T. Danks, W. H. Delany, J. V. Harris, J. Leadbeter, E. Morrish, W. J. Onions, F. Slater, and Cornelius Wood.

The present state of membership is as follows:—

|                          |     |     | <i>Honorary.</i> |     | <i>Ordinary,</i> |     |
|--------------------------|-----|-----|------------------|-----|------------------|-----|
| No. at beginning of year | ... | ... |                  | 49  |                  | 140 |
| Joined during the year   | ... | ... |                  | 2   |                  | 13  |
|                          |     |     |                  | 51  |                  | 153 |
| Resigned                 | ... | ... |                  |     | 4                |     |
| Struck off               | ... | ... | 2                | 2   | 10               | 14  |
|                          |     |     |                  |     |                  |     |
| Present number           | ... | ... |                  | 49  |                  | 139 |
|                          |     |     |                  | ... |                  |     |
| Total number April, 1898 | ... | 189 |                  |     |                  |     |
| " " April, 1899          | ... | 188 | Decrease ... 1   |     |                  |     |

May we again ask that each member will do his best to ensure that our members shall increase instead of decrease. It ought not to be a difficult matter to raise the membership to a minimum of 300.

The finances continue to improve, the balance on 31st December last, after paying all liabilities up to that date, being £47 7s. 7d., an increase of £6 8s. 5½d. during the year.

The Proceedings for the last Session are now being bound, and will be issued shortly. The delay has been chiefly caused by difficulties relating to the illustrations, of which there are a large number.

The Council will be pleased to receive offers of papers for the next session, and hope that it may be a record one, both for the number and quality of the papers presented, and the increase of members.

For the Council,

H. LE NEVE FOSTER, PRESIDENT.

WILLIAM H. CARDER, SECRETARY.

DUDLEY,

27th April, 1899.

**THE PRESIDENT :** There is one thing I should like to say about the report, and that is to remark upon the importance of trying to get more members. The more members we have, the greater will be the utility of the Institute. The reports will be spread over a wider field, and they should do a great deal of good. Our finances would also be in a more flourishing condition. Not that we have anything to complain of at present ; but we ought not to depend too much upon making a profit on the excursions. It would do a great deal of good not only to ourselves, but also to the district at large, if our Institute were, so to speak, better patronised. Are there any questions regarding this report which any gentleman would like to ask ? If so, either the Secretary or myself would be pleased to answer them.—[No questions.] I now propose, gentlemen, that the Annual Report and Balance Sheet be received and passed, and published in the Proceedings for the Session.

**MR. MOSES MILLARD :** I beg to second that. I am satisfied, in a certain sense, with the report, and I am also dissatisfied. We are all pleased, but more especially the Treasurer and the Trustees, that the balance is on the right side. With an Institute such as ours, we ought to make greater progress than we do. We are practically at a standstill, instead of moving on. We have every reason to encourage us to increase our membership. I take it, sir, that the privilege of being connected with an Institute of this sort, with its social relationships, and the friendly feeling there is amongst us, is in itself an ample recompense for the subscription we pay. But I prize it for even more than that. The literature that is issued is far and above the value of our contributions. You could not purchase it in the market for the money. Sometimes, when an interesting paper is being read, I look across and I see the intentness of the members, especially the younger ones, and while the discussion is on you can see the intelligence in their eye. All the interest and thought which these papers arouse, must of necessity tell upon the welfare of the trade of the district, and through the district, upon the commercial welfare of the country ; therefore, there is every reason and encouragement for those connected with the Institute to endeavour to obtain a good share of what, as far as we are concerned, may be termed the unproductive portion of the intelligence of the iron and steel trades which is lying dormant in South Staffordshire.

**MESSRS. WALTER JONES, WILLIAM YEOMANS, and L. D. THOMAS** also remarked upon the advisability of increasing the membership.

The proposition was then put to the meeting and carried unanimously.

**THE PRESIDENT :** The next business is the election of our President for the ensuing year, and I have great pleasure in proposing Mr. Harry Silvester for that position.

**MR. MOSES MILLARD** seconded the proposition, which was carried unanimously.

Mr. FOSTER now vacated the chair, which was taken by Mr. SILVESTER.

The newly-elected President, Mr. H. SILVESTER: Well, gentlemen, I shall, perhaps, have some difficulty in getting into the presidential mantle just fallen from Mr. Foster's shoulders, but whatever else may be the drawbacks of the Institute, a lack of generosity has never been one of them. I thank you very much. The next duty I have to perform is a very pleasing one, and that is to propose a vote of thanks to our retiring President, Mr. Le Neve Foster. You are all aware of his work during the session, and you heard his able presidential address, which, I am certain, added a great deal to the reputation of South Staffordshire. I propose a vote of thanks to the retiring President.

The proposition was seconded by Mr. W. YEOMANS, supported by Mr. R. EDWARDS, and carried unanimously.

Mr. LE NEVE FOSTER: I thank you very cordially for the kind vote of thanks. The work of an Institute like this is by no means lost altogether. The papers read at our various meetings bring new ideas to us, and the whole of the work that is done is beneficial to the district at large.

THE PRESIDENT: The next business on the Agenda is the election of Vice-president. Mr. L. D. Thomas is an old member, and has taken part in our proceedings for a considerable time, and I have pleasure in proposing him as Vice-president for the ensuing year.

The resolution was seconded by Mr. PIPER, supported by Mr. MILLWARD, and carried unanimously.

Mr. THOMAS: I thank you for the hearty manner in which you have proposed and adopted the resolution making me Vice-president, and I hope we shall never have cause to regret that you have put me in this position. So far as lies in my power you may rely that I will fulfil the duties of the office.

On the proposition of the PRESIDENT, seconded by Mr. H. LE NEVE FOSTER, Mr. James Piper was unanimously re-elected Treasurer.

On the proposition of the PRESIDENT, seconded by Mr. MOSES MILLARD, Mr. W. H. Carder was unanimously re-elected Secretary.

On the proposition of Mr. WALTER JONES, seconded by Mr. W. C. LITTLER, the following were elected as the Council for the ensuing year: Messrs, Thos. Ashton, George Barklam, William Bloor, William Brooks, Alfred Cookson, Richard Edwards, H. Le Neve Foster, John W. Hall, William John Hudson, Stephen Meredith, Richard Lythgoe, Moses Millard, Henry Parry, Thomas Pasfield, William B. Rubery, A. E. Tucker, Thomas Turley, Thomas Turner, George E. Vaughan, Herbert Whitehouse, and William Yeomans.

THE SECRETARY then read some correspondence with Messrs. Robert Heath and Sons, Limited, who wrote that they would be pleased for the members to visit their works during the coming Summer. Proposed by Mr. RICHARD EDWARDS, seconded by Mr. H. LE NEVE FOSTER, and carried, that the members visit Messrs. Heath and Sons' Works if the Council can make satisfactory arrangements.

The members afterwards dined together.

THE PRESIDENT (Mr. H. SILVESTER) presided, and was supported by the Mayor of Dudley (Alderman G. H. Dunn), Mr. R. Mentz Tolley, Mr. Walter Jones, etc. The Vice-president (Mr. L. D. Thomas) occupied the vice-chair.

After the loyal and patriotic toasts, the SECRETARY announced letters of apology from Sir Benjamin Hingley, Bart.; Sir Alfred Hickman, M.P.; Alderman G. H. Claughton, Mr. Francis Grazebrook, J.P.; Mr. Thomas Ashton, Mr. W. B. Rubery, Mr. A. E. Tucker, Mr. Thomas Parker, and others.

Mr. THOMAS TURNER (Past President): in proposing the toast of "The Iron, Steel, and Coal Trades of South Staffordshire," said that although we had not made so much progress as other ironmaking districts, yet there was plenty of reason to regard the iron and steel trades of the neighbourhood with satisfaction. He was told there were signs of a pig-iron famine. That, perhaps, was taking an extreme view; but when one remembered the deficiency of iron ores in the neighbourhood, and that abroad many of the sources of supply near the coast had been, to a great extent, exploited, and that ores had, therefore, to be brought from points further inland, and that many old works were standing for the time being, one could understand why iron had gone up in price, and that the rise was likely to continue. He wished, however, to point out that one of the greatest curses of the iron trade had been over speculation in times of good demand, and that we must look forward to a period of quiet trade, and see that our methods were in accordance with modern requirements. Referring to the increased prosperity of the coal trade, he said that it was a matter of great satisfaction that the boring on Lord Hatherton's Estate, north of Wolverhampton, had been successfully carried through. That meant an extension of the coalfield, an abundant supply of fuel, and prolonged life to the local industries. He gave the toast, coupling with it the names of The Mayor of Dudley and Mr. R. Mentz Tolley.

THE MAYOR OF DUDLEY, in responding for the Coal Trades, recounted some of his early experiences, and referred to the varied fuel requirements of the iron trade of fifty years ago and now. Personally, he was very glad to see an improved demand for iron and steel, for it always meant an increased price for coal.

Mr. R. MENTZ TOLLEY, in responding for the Iron and Steel Trades, said that the profitable future of the iron trade depended not so much upon the price obtained as upon the economies which could be effected, and with intelligent workmen and managers, economies could be made which at the end of the year would mean a profit instead of a loss. In certain branches of the trade there had not been a margin for one or two years. The production had been so great and so widespread, that it had been almost impossible to make a profit except by those who saved sixpence here and threepence there either by lessening the dead expenses or by lessening the consumption of raw material. To do that in the future, if we were to continue to produce far away from the sea coast where most of our works were situated, we must have in our works men of intelligence and ability. The previous night Sir John Gorst asked the House of Commons for 8½ millions for general educational purposes; and beyond that, about two millions a year was spent in technical education. There was a great outcry that boys were taken from school too early. 144,000 lads of 9, 10, and 11 years of age left school every year and went to work for wages, and out of those there were probably hardly 4,000 who could be said to have anything except the merest smattering of education. That sort of thing would produce in the end an ignorant man, an incapable man, an unprofitable servant; and therefore he asked that boys should not be taken from school too early, but that they should be kept at school until they were capable, not simply of learning the rudiments, but fit to go into technical classes where they could learn something of the iron, steel, coal, brick, and other local trades, and get a real knowledge of the ground work of the trade to which they would have to devote their lives. For instance, very few puddlers took any notice as to whether their coal was dry or wet; but if a puddler had been to a technical school he would know that all this wet had to be burnt away before an ounce of iron could be made, and so a little technical knowledge among the men could be of real assistance to the employer.

Mr. H. LE NEVE FOSTER proposed "The Institute," and urged its claims for better support from members of the iron and steel trades.

THE PRESIDENT: It is both a pleasure and a responsibility to respond to the toast which has been proposed by Mr. Foster. It is a pleasure because of the way in which you have honoured it; a responsibility because of the circumstances which have made it difficult to maintain the traditions of the Institute. Year after year the finances have improved; but when we come to look at the membership, there is something wanting. Some five years ago we had a total membership of 215. During the past three years the membership has fluctuated from 188 to 190. A short time ago I had a conversation with one of our past presidents, and his idea was that the title was restrictive. There must have been some good reason for changing the title from The Mill and

Forge Managers' Association, as it was originally called, to the present title; but if there is anything at all in the idea of the title affecting the prosperity of a society I should think it would be a good thing to call ourselves the South Staffordshire Iron and Steel Institute, which is at once a shorter and more euphonious title. This year we have made a new departure in changing the spot in which we have held our annual meeting. We have had one of the best attended gatherings for some years to commence the session with. In making the appeal, which every President makes, for papers, I may say that we expect to have some good ones during the coming session. I thank you very much for the way in which you have received the toast.

Mr. YEOMANS, in proposing the toast of "The Honorary Members," said the honorary members of the Institute had always been a source of strength to it. He retained very pleasant memories of his intercourse with them. There had been a great deal said about the advance which had been made by the Institute. He could remember the time when the honorary members used to meet at Stewponey and tell their customers how much iron they could have, and how much they should pay for it. They then used to have a good dinner and spend the evening on the bowling green. That state of things had gone, and the honorary members to-day, instead of telling customers how much iron they can have and how much they shall pay for it, have to look sharp to get anything.

Mr. WALTER JONES: I have attended a few meetings during this year and I am bound to say I have not only enjoyed them, but have learnt something. One evening this week I was at a meeting in London, and they were discussing the effect of American competition on the English markets, and what I gathered was this: That the Americans, although they pay higher wages than the English people, and pay, I believe, in some cases more than we do for their iron and coal, can yet bring their goods over here and sell them in the English market, and it was considered that one reason was that they get more out of their workpeople than we can. I asked why, and they said they thought it was the climate. I did not think it was the climate. There is a great deal in what has been said to-night, namely, that some of our workpeople want more technical education and more enlightenment. I want now to introduce some improvement in my own place in order to get a better output. 200 boxes per day are rammed up in America instead of 100 in England. I am going to try to get some of my men to do the same. A friend of mine in Birmingham makes cycle chains by the thousand and possibly by the million. They give special incentives to the men. They give out so many tools, and the men are paid a bonus of so much each if they can get more work out of a file than a certain amount. And there is also a bonus on saving gas. In every department they have

this bonus system. I tried it myself some time ago, but my experience was not satisfactory. But I shall try again. I must content myself now with thanking you all.

The remaining toasts were "The Vice-president," proposed by Mr. Jno. W. Hall, and responded to by Mr. L. D. Thomas; "The Past Presidents," and "The Guests."

THE SOUTH STAFFORDSHIRE INSTITUTE OF IRON & STEEL WORKS' MANAGERS.

BALANCE SHEET,

FOR YEAR ENDING 31st DECEMBER, 1898.

Dr.

Cr.

|                                    | £   | s. | d. |                                      | £    | s. | d.  |
|------------------------------------|-----|----|----|--------------------------------------|------|----|-----|
| To Balance brought forward ...     | 40  | 19 | 1½ | By Expenses at Annual Meeting ...    | 6    | 11 | 0   |
| " Subscriptions ...                | 117 | 17 | 3  | " Printing and Stationery ...        | 77   | 15 | 7   |
| " Books and Papers Sold ...        | 1   | 0  | 0  | " Shorthand Notes ...                | 12   | 2  | 10  |
| " Balance of Excursion Account ... | 21  | 13 | 1  | " Postages and Telegrams... ..       | 13   | 18 | 7½  |
| " Interest on Invested Funds ...   | 11  | 6  |    | " Carriage and Sundry Expenses ...   | 6    | 10 | 4   |
|                                    |     |    |    | " Bank Charges... ..                 | 5    | 0  |     |
|                                    |     |    |    | " Rent... ..                         | 7    | 10 | 0   |
|                                    |     |    |    | " Secretary's Honorarium ...         | 10   | 0  | 0   |
|                                    |     |    |    |                                      |      |    |     |
|                                    |     |    |    | Invested at 2½ per cent., £21 11 6 } | 134  | 13 | 4½  |
|                                    |     |    |    | In Treasurer's hands, £25 16 1 }     | 47   | 7  | 7   |
|                                    |     |    |    |                                      |      |    |     |
|                                    |     |    |    |                                      | £182 | 0  | 11½ |

Examined with Vouchers and found correct this 27th day of April, 1899.

WILLIAM WHITWORTH, } AUDITORS.  
WALTER W. PAGETT, }

## RULES.

REGISTERED No. 943, WORC.

1.—The Society shall be designated "The Staffordshire Iron and Steel Institute." Its registered office is in England, and is at The Institute, Wolverhampton-street, Dudley, in the County of Worcester. In the event of any change in the situation of the registered office, notice of such change shall be sent within fourteen days thereafter to the Registrar, in the form prescribed by the Treasury Regulations in that behalf.

2.—This Society is subject to the provisions of the Friendly Societies Act, 1875, except so much thereof as relates to dividing societies (section 11, sub-section 4); the certification of annuities (section 11, sub-section 5); appeals from a refusal to register a society or any amendment of the rules thereof (section 11, sub-sections 8 and 9, and section 13, sub-section 3); or from cancelling or suspension of registry (section 12, sub-section 4 and part of sub-section 5); quinquennial returns and valuations (section 14, sub-section 1, *a. f.*); certificates of death (section 14, sub-section 2, and section 15, sub-section 9); exemption from stamp duty (section 15, sub-section 2); nomination and distribution (section 15, sub-sections 3, 4, and 5); priority on death, bankruptcy, &c., of officers (section 15, sub-section 7); copyholds (section 16, sub-section 6); loans to members (section 18); the accumulation of surplus of contributions for members' use (section 19); so much of section 22 as relates to the reference of a dispute to the Chief or any other Registrar; the amalgamation, transfer of engagements, and dissolution of Friendly Societies (section 24, proviso to sub-section 8, and section 25, sub-section 1, *c.* and sub-section 7); militiamen and volunteers (section 26); the limitation of benefits (section 27); payments on the death of children (section 28); societies receiving contributions by collectors (section 30); cattle insurance and certain other societies (section 31); and the four last heads of Schedule II.

3.—The objects of the Institute are:—To promote the intellectual welfare of its members by periodical meetings for reading and discussing scientific papers on subjects connected with the Iron and Steel Trades, and such other matters as may be considered within the scope of the special authority of 3rd July, 1878 ("The Promotion of Literature, Science, and Fine Arts."). The expenses incurred in carrying out the above objects shall be provided by the subscriptions of Life and

Honorary Members, the entrance fees and periodical contributions of Ordinary Members, and from interest upon any accumulated capital.

#### CONSTITUTION.

4.—The Institute shall consist of Life, Honorary, and Ordinary Members, who shall be more than twenty-one years of age, and shall be either owners, managers, assistant managers, and other officials of iron and steel works, mechanical or mining engineers, analytical chemists, draughtsmen, or persons of scientific attainments in metallurgy, or specially connected with the application of iron and steel.

#### HONORARY MEMBERS.

5.—Any person connected with the Iron and Steel Trades may, on the invitation of the Secretary or other officer, become an Honorary Member of the Institute, on payment of One Guinea yearly to its funds, such payment to entitle him to receive invitations to all meetings of the Institute, and copies of all its publications. Any Honorary Member may become an Hon. Life Member by the payment of Ten Guineas.

#### ELECTION OF ORDINARY MEMBERS.

6.—Any person desirous of becoming an Ordinary Member of the Institute must be proposed and seconded, as provided by Form A in the Appendix.

7.—The election shall take place at an ordinary meeting ; a two-thirds majority of the members present being necessary for election.

8.—When the proposed candidate is elected, the Secretary shall give him notice thereof, according to Form B ; but his name shall not be added to the list of members of the Institute until he shall have paid his entrance fee and first annual subscription, and signed Form C in the Appendix.

9.—In the case of non-election, no mention thereof shall be made in the minutes, nor any notice be given to the unsuccessful candidate.

#### SUBSCRIPTIONS.

10.—The subscriptions for an Honorary Member shall be One Guinea per annum, and for an Honorary Life Member Ten Guineas, as provided by Rule 5. Each Ordinary Member shall pay an entrance fee of Two Shillings and Sixpence and an annual subscription of Ten Shillings and Sixpence ; or he may become an Ordinary Life Member by the payment of Five Guineas. All annual subscriptions shall be payable in advance, and shall be due on the First day of January in each year.

11.—Any member whose subscriptions shall be two years in arrear shall be thereby disqualified, and the Council, after having given due notice, in the Form D in the Appendix, shall remove his name from the list of members, unless satisfactory reasons are given to the contrary.

### OFFICERS.

12.—The officers of the Institute shall consist of a President, a Vice-president, Twenty-one Members of Council, Three Trustees, a Treasurer, and a Secretary, who shall be elected at the annual meeting by show of hands. The President, Vice-president, Treasurer, and Secretary shall be *ex-officio* members of the Committee of Management, herein termed Council. Officers may be removed by a special general meeting.

13.—In addition to the *ex-officio* members, the Council shall consist of Twenty-one Members, all of whom shall retire annually, but shall be eligible for re-election, with the exception of those who have not attended any of the Council Meetings called during the year for which they have been elected.

14.—The Council shall meet as often as the business of the Institute requires; seven to form a quorum. Such meeting to be called by the Secretary, of which seven clear days' notice shall be given.

15.—The Council shall appoint from its own body two Committees, one to be called the Finance Committee, which shall advise the Council on matters relating to the receipts and expenditure of the Institute; and the other to be called the Publication Committee, which shall arrange for suitable papers to be read at the meetings of the Institute, and shall undertake the revision of all printed transactions. The Council shall provide the Secretary with a sufficient number of copies of the Rules to enable him to deliver to any person on demand a copy of such rules, on payment of a sum not exceeding One Shilling; and it shall be the duty of the Secretary to deliver such copies accordingly.

### DUTIES OF OFFICERS.

16.—The President shall be chairman at all meetings at which he shall be present, and in his absence the Vice-president. In the absence of the Vice-president, the members shall elect a chairman for that meeting.

17.—The Treasurer shall hold in trust the uninvested funds of the Institute, which shall be deposited at a bank approved by the Council; he shall receive from the Secretary all amounts paid by way of subscription, contribution, or payment; and shall pay all accounts that are properly certified as correct by the President and Secretary. He shall keep proper books of account, and shall submit them once a year, or oftener if required by the Council, to the Auditors appointed, and shall supply the Secretary with a duplicate copy of his balance sheet.

18.—The Secretary shall attend all meetings, carry on the general business and correspondence of the Institute, arrange meetings for the reading of papers and for other purposes, and keep minutes of all proceedings, which shall be authenticated by the signature of the Chairman. He shall collect all subscriptions and pay the same to the Treasurer, and shall prepare and send the Returns required by the

Friendly Societies Acts and the Treasury Regulations to be sent to the Registrar. He shall be paid an honorarium on March 25th in each year, in addition to any sums he may expend on behalf of the Institute for postages, stationery, printing, or travelling expenses.

19.—The Trustees, each of whom must be a householder, and in whose names the properties and surplus funds of the Institute shall be invested, shall continue in office during the pleasure of the Institute, and in the event of any of them dying, resigning, or being removed from office, another or others shall be elected at the next general meeting of the Institute. A copy of every resolution appointing a Trustee shall be sent to the Registrar within fourteen days after the date of the meeting at which such resolution was passed, in the form prescribed by the Treasury Regulations in that behalf.

#### MEETINGS.

20.—The annual meeting shall be held in April in each year.

21.—General meetings shall be held as often as business requires. The place of such meetings to be decided at the previous annual meeting.

22.—The President or the Council, in case he or they at any time think it necessary, or the President, on the requisition of six members, may convene a special general meeting of the Institute, for the consideration of any subject requiring the immediate attention of members. The business of such meeting shall be confined to the special subjects named in the notice convening the same.

23.—All members shall have at least six clear days' notice of, and be entitled to attend, each meeting of the Institute, and to receive copies of the Institute's publications gratuitously.

24.—No alterations of the Rules shall be made except at a general meeting, and four weeks' notice in writing must be given to the Secretary of any proposed alterations. No amendment of Rules is valid until registered.

#### AUDITORS.

25.—The accounts, together with a general statement of the same, and all necessary vouchers, up to the 31st December then last, shall be submitted once in every year to two auditors appointed by the members at the general meeting preceding each annual meeting, who shall lay before every such meeting a balance sheet (which either may or may not be identical with the annual return, but must not be in contradiction to the same), showing the receipts and expenditure, funds and effects of the Institute, together with a statement of the affairs of the Institute since the last meeting, and of their then condition. Such Auditors shall have access to all the books and accounts of the Institute, and shall examine every balance sheet and annual return of the receipts and expenditure, funds and effects of the Institute, and shall verify the same with the accounts and vouchers relating thereto, and shall either sign the

same as found by them to be correct, duly vouched, and in accordance with law ; or shall specially report to the meeting of the Society before which the same is laid in what respects they find it incorrect, unvouched, or not in accordance with law ; and the balance sheet or report shall be published in the *Proceedings* of the Institute.

#### COMMUNICATIONS OF MEMBERS AND OTHERS.

26.—All communications shall be submitted to the Council, and after their approval, shall be read at the general meetings. All communications shall be the property of the Institute, and shall be published only in the *Proceedings* of the Institute, or by the authority of the Council.

#### PROPERTY OF THE INSTITUTE.

27.—All books, communications, drawings, and the like shall be accessible to all the members. The Council shall have power to deposit the same in such place or places as may be considered most convenient for the members.

#### INVESTMENT OF FUNDS.

28.—As much of the funds of the Institute as may not be wanted for immediate use, or to meet the usual accruing liabilities, shall, with the consent of the Council, or of a majority of the members of the Institute present at a General Meeting, be invested by the Trustees in such of the following ways as the Council or General Meeting shall direct, namely, in the Post Office Savings Bank, in the Public Funds, or with the Commissioners for the Reduction of the National Debt, upon Government or real securities in Great Britain, or upon the security of any County, Borough, or other rates authorised to be levied and mortgaged by Act of Parliament.

#### ANNUAL AND OTHER RETURNS.

29.—It shall be the duty of the Committee of Management to keep a copy of the last annual balance sheet of the Society for the time being, together with the Report of the Auditors, if any, always hung up in a conspicuous place at the Registered Office of the Society.—Friendly Societies Act, 1875, s. 14 (1 i.).

30.—The books and accounts of the Society shall be open to the inspection of any member or person having an interest in the funds of the Society at all reasonable times, at the registered office of the Society, or at any place where the same are kept, and it shall be the duty of the Secretary to produce them for inspection accordingly.

31.—Every year before the 1st June, the Committee of Management shall cause the Secretary to send to the Registrar the annual return, in the form prescribed by the Chief Registrar of Friendly Societies, required by the Friendly Societies Act, 1875, of the receipts and expenditure, funds and effects of the Society, and of the number of members of the same, up to the 31st December then last inclusively, as audited and laid

before a General Meeting showing separately the expenditure in respect of the several objects of the Society, together with a copy of the Auditor's Report, if any.

32.—Such return shall state whether the audit has been conducted by a public auditor appointed under the Friendly Societies Act, 1875, and by whom, and if such audit has been conducted by any persons other than a public auditor, shall state the name, address, and calling or profession of each of such persons, and the manner in which, and the authority under which, they were respectively appointed.—Friendly Societies Act, 1875, s. 14 (1 *d.*).

33.—It shall be the duty of the Committee of Management to provide the Secretary with a sufficient number of copies of the annual return, or of some balance sheet, or other document duly audited containing the same particulars as in the annual return as to the receipts and expenditure, funds and effects of the Society, for supplying gratuitously every member or person interested in the funds of the Society, on his application, with a copy of the last annual return of the Society, or of such balance sheet or other document as aforesaid, for the time being, and it shall be the duty of the Secretary to supply such gratuitous copies on application accordingly.—Friendly Societies Act, 1875, s. 14 (1 *h.*).

#### DISSOLUTION.

34.—The Society may at any time be dissolved by the consent of three-fourths of the members, including honorary members, if any, testified by their signatures, to some instrument of dissolution in the form provided by the Treasury Regulations in that behalf.

#### DISPUTES.

35.—If any dispute shall arise between a member, or person claiming through a member, or under the Rules of the Society, and the Society, or any officer thereof, it shall be referred to justices pursuant to the Friendly Societies Act, 1875, s. 22 (*c.*).

## APPENDIX.

## FORM A.

## THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Mr.

of \_\_\_\_\_ being desirous of becoming  
a member of the Institute, we, the undersigned, believing him to be  
fully eligible, hereby recommend him for election.

His qualifications are

Witness our hands this \_\_\_\_\_ day of \_\_\_\_\_ 19

} Names of two members.

This application shall be considered by a Committee, consisting of  
the President and Vice-president (for the time being), and the Secretary,  
and if they approve of the application, it shall be submitted to a General  
Meeting for refusal or adoption.

## FORM B.

## THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

To

Sir,

I beg to inform you that on the  
you were elected a member of The Staffordshire Iron and Steel Institute;  
but in conformity with the Rules, your election cannot be confirmed until  
the accompanying form be returned with your signature, together with  
your Entrance Fee and first Annual Subscription. (Amount,  
£ \_\_\_\_\_ s. \_\_\_\_\_ d.)

If this amount be not received in one month from this date, your  
election will become void.

I am, Sir,

Yours truly,

Secretary.

day of

19

## FORM C.

## THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

I, the undersigned, being elected a member of The Staffordshire Iron and Steel Institute, do hereby agree that I will be governed by the rules of the Institute, and that I will advance its interests as far as may be in my power, provided that if I signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after paying all arrears which may be due by me at that period) be free from this obligation.

Witness my hand this

day of

19

Member's Signature.  

---

## FORM D.

## THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

DEAR SIR,

I am directed by the Council to inform you that your subscription to the Institute, amounting to  
is still in arrear, and that if the same be not paid to me on or before the  
day of your name will be  
removed from the lists of the Institute.

Yours faithfully,

Secretary.

**OFFICERS FOR SESSION 1899-1900.**  

---

**President :****H. SILVESTER.****Vice-president :****L. D. THOMAS.****Trustees :****ALFRED COOKSON, MOSES MILLARD, WILLIAM B. RUBERY.****Treasurer :****JAMES PIPER.****Council :****THOMAS ASHTON****GEO. BARKLAM****WILLIAM BLOOR****WILLIAM BROOKS****ALFRED COOKSON****RICHARD EDWARDS****H. LE NEVE FOSTER****J. W. HALL****W. JNO. HUDSON****STEPHEN MEREDITH****R. LYTHGOE****MOSES MILLARD****HENRY PARRY****THOMAS PASFIELD****WILLIAM B. RUBERY****ALEXANDER E. TUCKER****T. TURLEY****THOMAS TURNER****G. E. VAUGHAN****HERBERT WHITEHOUSE****WILLIAM YEOMANS****Secretary :****WILLIAM H. CARDER, Alwen Street, Wordsley, near Stourbridge.**

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**PAST PRESIDENTS.**

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|                                 |                            |
|---------------------------------|----------------------------|
| 1866.—WILLIAM LESTER            | 1883.—MOSES MILLARD        |
| 1867.—JOHN BROWN                | 1884.—WILLIAM JNO. HUDSON  |
| 1868.—JOHN WRIGHT               | 1885.—RICHARD SMITH CASSON |
| 1869.—SAMUEL NEWTON             | 1886.—HENRY FISHER         |
| 1870.—WILLIAM EDWARDS           | 1887.—GEORGE B. WRIGHT     |
| 1871.—JOHN FINNEMORE            | 1888.—HENRY PARRY          |
| 1872.—AMBROSE BEARDS            | 1889.—ALEXR. E. TUCKER     |
| 1873.—JOHN FIELDHOUSE           | 1890.—HERBERT PILKINGTON   |
| 1874.—WILLIAM MOLINEAUX         | 1891.—HERBERT PILKINGTON   |
| 1875.—HENRY HUGHES              | 1892.—THOMAS TURNER        |
| 1876.—WILLIAM FARNWORTH         | 1893.—JAMES ROBERTS        |
| 1877.—JOHN WRIGHT (second time) | 1894.—THOMAS ASHTON        |
| 1878.—WALTER HEELEY             | 1895.—WILLIAM B. RUBERY    |
| 1879.—JAMES RIGBY               | 1896.—WILLIAM YEOMANS      |
| 1880.—EDWARD HARRIS             | 1897.—JNO. W. HALL         |
| 1881.—JOSEPH MORRIS             | 1898.—H. LE NEVE FOSTER    |
| 1882.—RICHARD EDWARDS           |                            |

**LIST OF MEMBERS.**

(CORRECTED TO 25TH MARCH, 1900).

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**HONORARY MEMBERS.**

---

- Adams, George, and Sons (Ld.),  
*Mars Ironworks, Wolverhampton.*
- Akrill, C., and Co.,  
*Gold's Green Foundry, West Bromwich.*
- Bayliss, Jones, and Bayliss,  
*Victoria Works, Wolverhampton.*
- Bantock, Thos., and Co.,  
*Wolverhampton.*
- Bohler Brothers and Co.,  
*Pond Hill, Sheffield.*
- Bromford Iron Co.,  
*West Bromwich.*
- Bunch, B. and Sons,  
*Staffordshire Ironworks, Walsall.*
- Chatwin, Thomas,  
*Market Foundry, Tipton.*
- Cochrane and Co.,  
*Woodside Ironworks, Dudley.*
- Dudley, Earl of,  
*Priory Offices, Dudley.*
- Gilchrist, P.C., F.R.S. (Life),  
*Frogna! Bank, Finchley Road, Hampstead, London, N. W.*
- Grazebrook, M. and W.,  
*Netherton Ironworks, near Dudley.*

- 
- st, Josiah,  
*Victoria Foundry, West Bromwich.*
- ria, Peter, J.P.,  
*The Elms, Brierley-Hill.*
- rison, G. King,  
*Lye Fire-clay and Brick Works, Stourbridge.*
- rman, A., Limited,  
*Spring Vale Furnaces, near Wolverhampton.*
- gley, N. and Sons, Limited,  
*Netherton Ironworks, Dudley.*
- chinson, W.,  
*Penn House, Wolverhampton.*
- s, J. Skidmore,  
*The Hollies, Rowley Regis, near Dudley.*
- s, Walter,  
*Holly Mount, Red Hill, Stourbridge.*
- y, E. C. and J. Limited,  
*Princes Chambers, Corporation-street, Birmingham.*
- i, Henry,  
*19, Marsh Side, Workington.*
- ght and Crowther, Limited,  
*Stour Vale Works, Kidderminster.*
- wles, J.  
*Wolseley House, Wednesbury.*
- gham, J. W.  
*Bush Farm Ironworks, West Bromwich.*
- shall Co., Limited,  
*Priors Lee Hall, near Shifnal.*
- d, F. H. and Co., Limited,  
*James Bridge Steel Works, near Wednesbury.*
- s, Vernon, and Holden,  
*Smethwick, near Birmingham.*
- ean, Alexander, J.P.,  
*Lichfield-street, Wolverhampton.*

- Parkes, E., and Co.,  
*Atlas Ironworks, West Bromwich.*
- Parkes, H. P., and Co., Limited,  
*Tipton Green Works, Tipton.*
- Patchett, Colonel Jas.,  
*Shropshire Iron Co., Limited, Hadley, near Wellington, Sa*
- Patent Shaft and Axletree Co., Limited,  
*Wednesbury.*
- Pearson, J. H.,  
*Netherton Furnaces, near Dudley.*
- Perry, James,  
*69, Finch Road, Handsworth, Birmingham.*
- Perry, T., and Son, Limited,  
*Highfield Works, Bilston.*
- Punnett, H. M.,  
*53, Hagley Road, Birmingham.*
- Roberts and Cooper,  
*Brierley-Hill.*
- Roberts, J. and S., Limited,  
*West Bromwich.*
- Russell, Jno., and Co., Limited,  
*Cyclops Ironworks, Walsall.*
- Siemens, F.,  
*10, Queen Anne's Gate, Westminster, S.W.*
- Simpson, F. F.,  
*Park Lane Ironworks, Oldbury.*
- Spencer, John, Limited,  
*Globe Tube Works, Wednesbury.*
- Summers, J.,  
*Globe Ironworks, Stalybridge.*
- Tangyes, Limited,  
*Cornwall Works, Birmingham.*
- Taylor and Farley,  
*Summit Foundry, West Bromwich.*

- er, J. G.,  
*7, Trindle Road, Dudley.*
- o, H. A.,  
*Church-street Chambers, Stourbridge.*
- ley, W.,  
*Shaw Road, Dudley.*
- inson, T. A.,  
*1, Merridale Road, Wolverhampton.*

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 ORDINARY MEMBERS.
 

---

- , J.,  
*303, Bromford Lane, West Bromwich.*
- on, T.,  
*Church Road, Netherton, near Dudley.*
- l, G. B.,  
*Wellington Road, Bilston.*
- ury, J.,  
*Smethwick Foundry, Smethwick, near Birmingham.*
- ood, W. W.,  
*Tipton Engineering Works, Tipton.*
- r, Alexr., J.,  
*Grassington, Green-street, Smethwick.*
- r, Wm. T.,  
*71, Hillary Street, Walsall.*
- s, A. R.,  
*11, High-street, West Bromwich.*
- lam, Geo.,  
*167, Dudley Port, Tipton.*
- Jno.,  
*Banford House, Haden Hill, Old Hill, Staffs.*
- er, Joseph,  
*67, Beeches Road, West Bromwich.*
- s, Thomas,  
*Jervoise-street, West Bromwich.*

- Bostock, W. H.,  
*Steel and Ironworks, Darlaston.*
- Bloor, W.,  
*Portfield, Dudley Port, Tipton.*
- Bradley, B. G.,  
*Codsall House, near Wolverhampton.*
- Bradley, R. W.,  
*Caponfield Furnaces, Bilston.*
- Broadbent, Thomas,  
*51, Powke Lane, Old Hill, near Dudley.*
- Brooks, W.,  
*17, Wellington Road, Dudley.*
- Browett, T. B.,  
*91, Chester Road, Kidderminster.*
- Brown, Joseph,  
*Sedgley, near Dudley.*
- Brown, S. J.,  
*Gold's Hill Post Office, West Bromwich.*
- Bryce, D.,  
*Pensnett, Dudley.*
- Burt, Jabez,  
*40, Dudley Road, West Bromwich.*
- Burt, Joseph,  
*Oak Road, West Bromwich.*
- Burton, Wingfield,  
*Albert House, Bilston.*
- Carder, W. H.,  
*29, Alwen-street, Wordsley, Stourbridge.*
- Chambers, Jos. Jno.,  
*Handel House, Brockmoor, Brierley-Hill.*
- Colley, J.,  
*Hillingdon, Dover-street, Bilston.*
- Cookson, A.,  
*Coalbournbrook, Stourbridge.*
- Crofts, D.,  
*Woodsetton, Dudley.*
- Darby, Jno. W.,  
*39, Parliament-street, Bury, Lancashire.*

- E. Albert,  
*89, North Road, Wolverhampton.*
- Michael,  
*Netherton Furnaces, Dudley.*
- ay, James,  
*Tipton Green House, Tipton.*
- G.,  
*6, Bradley-street, Burnt Tree, Tipton.*
- ls, R.,  
*70, Corporation-street, West, Walsall.*
- D.,  
*Plant-street, Old Hill, near Dudley.*
- rth, E.,  
*Rosslyn, Goldthorn Hill, Wolverhampton.*
- ton, R. H.,  
*The Manor House, Norton-in-the-Moors, near Stoke-on-Trent.*
- t, John,  
*Cradley Heath, Staffs.*
- use, J.,  
*94, St. Paul's Road, West Smethwick.*
- James,  
*Dudley Road, West Bromwich.*
- Walter,  
*Clarence House, Coseley, Bilston.*
- r, E.,  
*81, Thornaby Road, Thornaby-on-Tees.*
- H. Le Neve,  
*Athenæum Chambers, Temple Row, Birmingham.*
- W. J.,  
*Arnside House, Gordon-street, Darlaston.*
- George, Ironfounder,  
*Pensnett, near Dudley.*
- Wm. H.,  
*19, Broomhill Road, Old Whittington, Chesterfield.*
- W. Lloyd,  
*Sheepwash Lane, Great Bridge.*
- ood, W. H.,  
*Hardwicke House, Carpenter Road, Edgbaston, Birmingham.*

- Grice, J.,  
*Fox Yards, Tipton.*
- Griffin, Edward B.,  
*Fullwood's End, Coseley, Bilston.*
- Hall, J. W.,  
*Athenaeum Chambers, 71, Temple Row, Birmingham.*
- Hall, R.,  
*Eltingshall Villa, near Wolverhampton.*
- Hammond, H. A.,  
*Hargate House, West Bromwich.*
- Hammond, Herbert,  
*Greenfield House, Cradley Heath, Staffordshire.*
- Harley, John,  
*Wolverhampton.*
- Harper, A.,  
*22, Westbourne-street, Stockton-on-Tees.*
- Harper, Emmanuel,  
*Cox's Lane, Old Hill, near Dudley.*
- Harris, E.,  
*New-street, St. George's near Wellington, Salop.*
- Harrison, J.,  
*22, Wreatham Road, Handsworth, Birmingham.*
- Hartland, H.,  
*Ruilton, near Dudley.*
- Haskew, Frederick J.,  
*High-street, Stourbridge.*
- Haslam, Henry B.,  
*The Mount, Bank Road, Coseley, Bilston.*
- Hatfield, J. A.,  
*89, Bridge-street, Wednesbury.*
- Hawkins, W. R.,  
*The Crown Foundry, Dudley Port, Tipton.*
- Hedley R.,  
*Grange Villa, Mount Pleasant, Spennymoor.*

- rs, Charles H.,  
60, Reid-street, Crewe.
- s, Geo.,  
1, Auckland Road, Smethwick, Birmingham.
- rkiss, Thos.,  
King's Hill Villa, Wednesbury.
- ate, T. E.,  
173, Hollins Grove, Darwen.
- e, W. H.,  
7, Beeches Road, West Bromwich.
- on, W. J. (Life),  
Corngreaves Furnaces, Cradley, Staffs.
- on, A. W.,  
Clay Cross Co., near Chesterfield.
- , Greville, T.,  
Clarence Ironworks, Port Clarence, Middlesbro'-on-Tees.
- , R. E.,  
Whitwell, near Chesterfield.
- rick, W.,  
Clarence House, Carter's Green, West Bromwich.
- er, N. W.,  
Islip House, Thrapston.
- e, G. C.,  
181, Bloxwich Road, Walsall.
- , A. H.,  
Oldswinford, near Stourbridge.
- ix, L. Gordon, J. P.,  
Newbridge Works, Pontypridd.
- , Isaac E.,  
Jamálpur, Bengal, India.
- , John,  
Caldwall Foundry, Kidderminster.
- , W. C.,  
13, Church-street, Bloxwich, Walsall.

- Lloyd, J. M.,  
*Cleveland House, Priestfield, Wolverhampton.*
- Lones, T. E.,  
*The Patent Office, 25, Southampton Buildings, Chancery Lane,  
London, W.C.*
- Lycett, J. A.,  
*Burnt Tree House, Tipton.*
- Lythgoe, Richard,  
*Dudley House, Brierley-Hill.*
- McMillan, W. G.,  
*8, Leigham Court Road, West Streatham, London, S.W.*
- Matty, W. H.,  
*Langley, near Birmingham.*
- Melland, G.,  
*Mason College, Birmingham.*
- Meredith, S.,  
*Tividale Road, Tipton.*
- Micklewright, William,  
*Mount House, Mount-street, Walsall.*
- Millard, M.,  
*Oakleigh, Humber Road, Wolverhampton.*
- Mills, Frederick,  
*Ebbw Vale Steel, Iron, and Coal Company, Limited, Ebbw  
Vale, R.S.O., Mon.*
- Millward, G. A.,  
*Sidmouth Avenue, Newcastle, Staffs.*
- Millward, Thos.,  
*The Elms, Clensmore, Kidderminster.*
- Molineaux, W. Jun.,  
*106, Oxford-street, Bilston.*
- Moore, William,  
*Spring Vale House, Ettingshall Wolverhampton.*
- Nicholls, James,  
*Round Oak, Brierley-Hill.*
- Nicholson, E. D.,  
*Llyncllys, near Oswestry.*

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*Highfields, Bradley, Bilston.*
- rs, Frank East,  
*Eastcroft, Grange Road, West Bromwich.*
- rs, Joseph,  
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- rs, W. W.,  
*Wollaston, Stourbridge.*
- rs, H.,  
*The Level New Furnaces, Brierley-Hill.*
- rs, H. E.,  
*13, Carter's Green, West Bromwich.*
- rs, T.,  
*24, Wellington Road, Dudley.*
- rs John (Life),  
*Belle Isle Place, Workington.*
- rs, J. E.,  
*54, Rookery Road, Handsworth, near Birmingham.*
- rs, J.,  
*67, Woodland Road, Handsworth, Birmingham.*
- rs, H. (Life),  
*Sheepbridge Ironworks, Chesterfield.*
- rs, J.,  
*Collis-street, Stourbridge.*
- rs, A.,  
*Mount Pleasant, Bilston.*
- rs, James,  
*Pensnett Road, Brierley-Hill.*
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*Vulcan Foundry, Darlaston.*
- rs, Jno.,  
*Sedgley Road, Tipton.*
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*Garland Cottages, Neptune-street, Tipton.*

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- Robinson, John,  
*Wood Lane, Hayton Quarry, near Liverpool.*
- Round, R.,  
*91, Moor-street, Brierley-Hill.*
- Rubery, W. B.,  
*76, Dudley Road, Tipton.*
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*Jesson-street, West Bromwich.*
- Scott, David,  
*Inglenook, Pennfields, Wolverhampton.*
- Shakell, W. H. S.,  
*94, Putney Road, Handsworth, Birmingham.*
- Shedden, Duncan J.,  
*Dixon's Green, Dudley.*
- Silvester, H.,  
*78, Holyhead Road, Handsworth.*
- Simpson, Brough,  
*Dixon's Green, Dudley.*
- Skidmore, J.,  
*30, Titford Road, Langley, Oldbury.*
- Smith, T. H.,  
*Princes End Foundry, Tipton.*
- Spraggett, P. E.,  
*Eaton House, Montague Road, Handsworth, Birmingham.*
- Summers, Geo. W.,  
*Mount Pleasant, Coseley, Bilston.*
- Thomas, E. F.,  
*Birchills Ironworks, Walsall.*
- Thomas, F. G.,  
*Birchills Ironworks, Walsall.*
- Thomas, L. D.,  
*Bromley House, Pensnett, near Dudley.*
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*The Cleveland, Wolverhampton.*
- Thompson, E. S.,  
*Bradley Boiler Works, Bilston.*
- Tolley, R. M.,  
*Darlaston Steel Works, Darlaston.*
- Toy, Harry B.,  
*Ingladene, 19, Lodge Road, West Bromwich.*

- Treglown, C. H.,  
*38, Wretham Road, Handsworth, Birmingham.*
- Tucker, A. E.,  
*35, Paradise-street, Birmingham.*
- Turley, T.,  
*Hill View, Woodsetton, near Dudley.*
- Turner, T.,  
*Ravenhurst. Rowley Park. Stafford.*
- Vaughan, Geo. Ed.,  
*Junction Villa, Carter's Green, West Bromwich.*
- Venables, W. H.,  
*Farringsford, Vicarage Road. Smethwick.*
- Walton, Jos. P.,  
*c/o Consett Iron and Steel Works, Blackhill, Co. Durham.*
- Westwood, Samuel,  
*Bank Farm, Graveyard Road, Lower Gornal, near Dudley.*
- Whitehouse, Herbert,  
*Phoenix-street, West Bromwich.*
- Whitmore, Samuel,  
*Siran Garden Villa, Wolverhampton.*
- Whittaker, J. H.,  
*Cherry Orchard, Kidderminster.*
- Whitworth, Wm.,  
*The Cliff, Wordsley, Stourbridge.*
- Wilcox, Richard,  
*Maltmill Lane, Blackheath, Staffs.*
- Willcox, Thomas,  
*2, District Terrace. Brasshouse Lane, Smethwick.*
- Williams, A.,  
*Arnside, Gordon-street, Darlaston.*
- Williams, G.,  
*Parkbridge Ironworks, Ashton-under-Lyne.*
- Winwood, Thomas,  
*The Hollies, Pensnett, near Dudley.*
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*Talbot-street, Brierley-Hill.*
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| No. in Catalogue | Title.                                                                                                 | By whom Presented.    |
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| 84               | Proceedings of South Staffordshire Institute of Iron and Steel Works' Managers, 1898-99. Vol. XIV. ... | The Institute.        |
| 157              | Journal of the Iron & Steel Institute, 1899. Vol. I. ...                                               | Do.                   |
| 158              | Do. do. 1899. Vol. II. ...                                                                             | Do.                   |
| 262              | Transactions of the American Society of Mechanical Engineers ...                                       | The Society.          |
| 326              | Journal of the West of Scotland Iron and Steel Institute, 1898-1899. Vol. VI. ...                      | The Institute.        |
| 356              | Proceedings of the Nova Scotian Institute of Science, 1897-1898 ...                                    | Do.                   |
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| 402              | Proceedings of the Institution of Mechanical Engineers, 1899 ...                                       | The Institution.      |
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| 54  | Lime as a Flux in Blast Furnace Practice, and other papers, C. Cochrane.                                    |     |                        |                       |
| 55  | Momentary Depression of the Elastic Limit of Steel, at two Critical Temperatures. Henry M. Howe, A.M., S.B. |     |                        |                       |
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| 356 | Do.                                                                                                                              | do.                                         | do. | 1897-98           |
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| 386 | An improved method of utilizing Canals for Traffic, W. B. Cook and F. Willoughby. |
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THE THWAITE GARDNER BLAST FURNACE POWER SYSTEM  
COPY OF DIAGRAM FROM A GAS ENGINE  
USING BLAST FURNAOE GAS

FROM

COKE FED FURNAOES.

400 300 200

100 0 100 200 300 400 500 600 700 800 900 1000

100 200 300 400 500 600 700 800 900 1000

400 300 200

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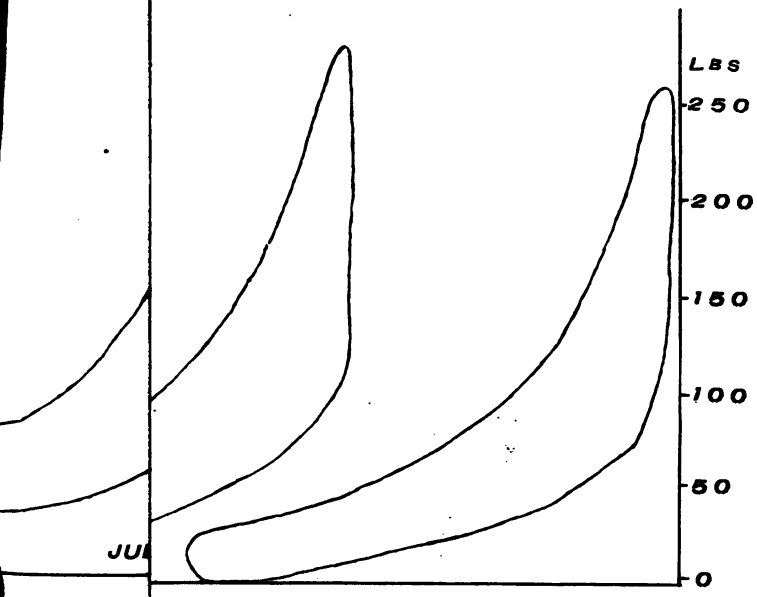
| Year                          | 1860 | 1864 | 1890 | 1892 | 1897 |
|-------------------------------|------|------|------|------|------|
| Population                    |      |      |      |      |      |
| Area                          |      |      |      |      |      |
| Water                         |      |      |      |      |      |
| Total                         |      |      |      |      |      |
| Per capita                    |      |      |      |      |      |
| Value added                   |      |      |      |      |      |
| Exports                       |      |      |      |      |      |
| Imports                       |      |      |      |      |      |
| Balance of trade              |      |      |      |      |      |
| Government revenue            |      |      |      |      |      |
| Government expenditure        |      |      |      |      |      |
| Public debt                   |      |      |      |      |      |
| Military expenditure          |      |      |      |      |      |
| Educational expenditure       |      |      |      |      |      |
| Health expenditure            |      |      |      |      |      |
| Social welfare expenditure    |      |      |      |      |      |
| Other public expenditure      |      |      |      |      |      |
| Unemployment                  |      |      |      |      |      |
| Inflation rate                |      |      |      |      |      |
| Interest rate                 |      |      |      |      |      |
| Money supply                  |      |      |      |      |      |
| GDP growth rate               |      |      |      |      |      |
| Industrial production index   |      |      |      |      |      |
| Retail price index            |      |      |      |      |      |
| Consumer price index          |      |      |      |      |      |
| Wholesale price index         |      |      |      |      |      |
| Manufacturing output index    |      |      |      |      |      |
| Agriculture output index      |      |      |      |      |      |
| Services output index         |      |      |      |      |      |
| Construction output index     |      |      |      |      |      |
| Energy consumption index      |      |      |      |      |      |
| Electricity generation index  |      |      |      |      |      |
| Transportation index          |      |      |      |      |      |
| Communication index           |      |      |      |      |      |
| Finance index                 |      |      |      |      |      |
| Real estate index             |      |      |      |      |      |
| Stock market index            |      |      |      |      |      |
| Bond market index             |      |      |      |      |      |
| Currency exchange rate        |      |      |      |      |      |
| Gold standard                 |      |      |      |      |      |
| Free trade                    |      |      |      |      |      |
| Protectionism                 |      |      |      |      |      |
| Tariffs                       |      |      |      |      |      |
| Subsidies                     |      |      |      |      |      |
| Trade agreements              |      |      |      |      |      |
| Customs union                 |      |      |      |      |      |
| Common market                 |      |      |      |      |      |
| European Union                |      |      |      |      |      |
| NATO                          |      |      |      |      |      |
| World War I                   |      |      |      |      |      |
| World War II                  |      |      |      |      |      |
| Korean War                    |      |      |      |      |      |
| Vietnam War                   |      |      |      |      |      |
| Gulf War                      |      |      |      |      |      |
| Yugoslav Wars                 |      |      |      |      |      |
| War in Afghanistan            |      |      |      |      |      |
| War in Iraq                   |      |      |      |      |      |
| War in Syria                  |      |      |      |      |      |
| War in Yemen                  |      |      |      |      |      |
| War in Libya                  |      |      |      |      |      |
| War in Sudan                  |      |      |      |      |      |
| War in Chad                   |      |      |      |      |      |
| War in Congo                  |      |      |      |      |      |
| War in Angola                 |      |      |      |      |      |
| War in Mozambique             |      |      |      |      |      |
| War in Zimbabwe               |      |      |      |      |      |
| War in Botswana               |      |      |      |      |      |
| War in Namibia                |      |      |      |      |      |
| War in South Africa           |      |      |      |      |      |
| War in Israel                 |      |      |      |      |      |
| War in Lebanon                |      |      |      |      |      |
| War in Cyprus                 |      |      |      |      |      |
| War in Greece                 |      |      |      |      |      |
| War in Turkey                 |      |      |      |      |      |
| War in Bulgaria               |      |      |      |      |      |
| War in Romania                |      |      |      |      |      |
| War in Hungary                |      |      |      |      |      |
| War in Poland                 |      |      |      |      |      |
| War in Czech Republic         |      |      |      |      |      |
| War in Slovakia               |      |      |      |      |      |
| War in Austria                |      |      |      |      |      |
| War in Switzerland            |      |      |      |      |      |
| War in Germany                |      |      |      |      |      |
| War in France                 |      |      |      |      |      |
| War in Italy                  |      |      |      |      |      |
| War in Spain                  |      |      |      |      |      |
| War in Portugal               |      |      |      |      |      |
| War in Ireland                |      |      |      |      |      |
| War in United Kingdom         |      |      |      |      |      |
| War in Netherlands            |      |      |      |      |      |
| War in Belgium                |      |      |      |      |      |
| War in Luxembourg             |      |      |      |      |      |
| War in Denmark                |      |      |      |      |      |
| War in Sweden                 |      |      |      |      |      |
| War in Norway                 |      |      |      |      |      |
| War in Finland                |      |      |      |      |      |
| War in Estonia                |      |      |      |      |      |
| War in Latvia                 |      |      |      |      |      |
| War in Lithuania              |      |      |      |      |      |
| War in Ukraine                |      |      |      |      |      |
| War in Russia                 |      |      |      |      |      |
| War in Belarus                |      |      |      |      |      |
| War in Kazakhstan             |      |      |      |      |      |
| War in Kyrgyzstan             |      |      |      |      |      |
| War in Tajikistan             |      |      |      |      |      |
| War in Uzbekistan             |      |      |      |      |      |
| War in Turkmenistan           |      |      |      |      |      |
| War in Azerbaijan             |      |      |      |      |      |
| War in Armenia                |      |      |      |      |      |
| War in Georgia                |      |      |      |      |      |
| War in Albania                |      |      |      |      |      |
| War in Kosovo                 |      |      |      |      |      |
| War in Macedonia              |      |      |      |      |      |
| War in Serbia                 |      |      |      |      |      |
| War in Montenegro             |      |      |      |      |      |
| War in Bosnia and Herzegovina |      |      |      |      |      |
| War in Croatia                |      |      |      |      |      |
| War in Slovenia               |      |      |      |      |      |
| War in Hungary                |      |      |      |      |      |

*Fig. IV.*

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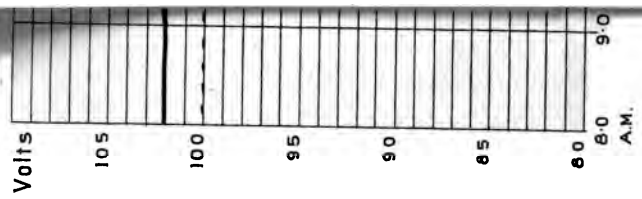
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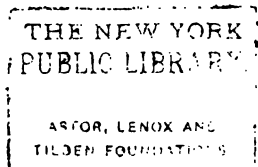


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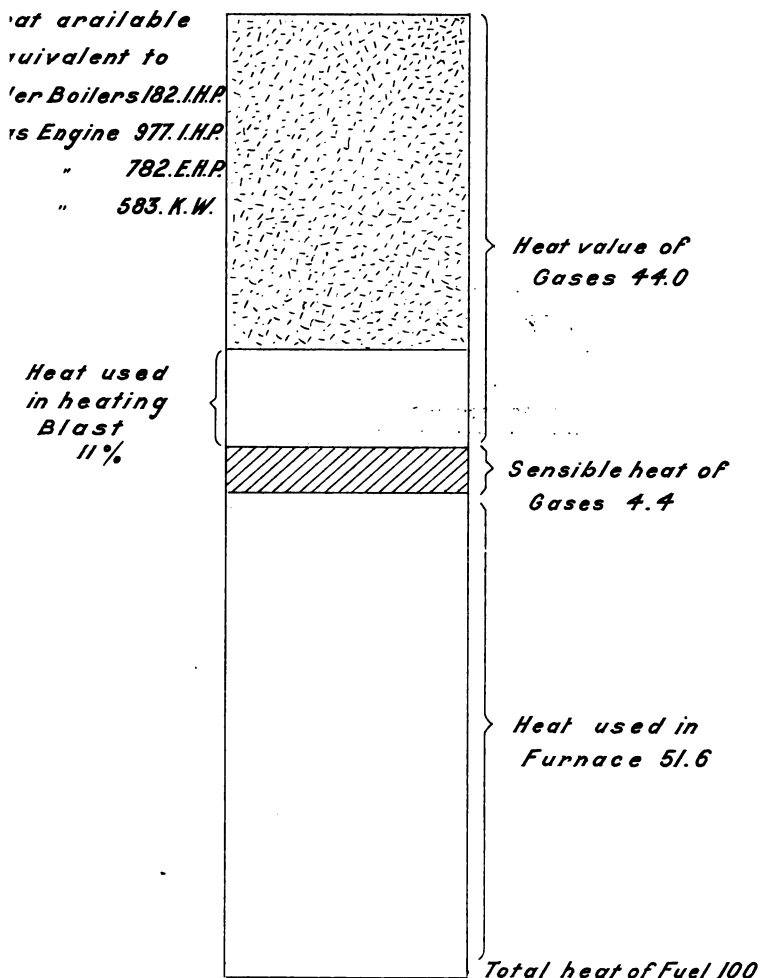
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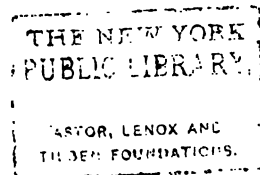
## — DIAGRAM —

*Showing Utilization of Heat Energy  
in a Blast Furnace using Coal.*

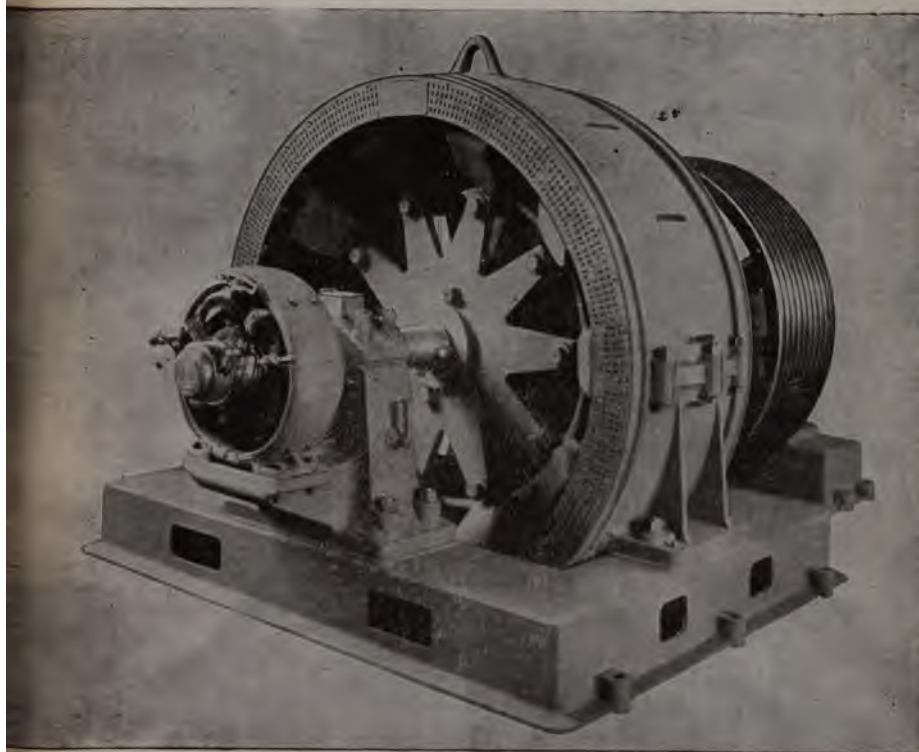


*Fig X*

value of this Fuel tested in Thompson's Calorimeter gave 14,000 B



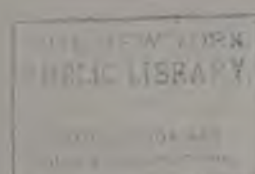
MR. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN  
MINES AND IRONWORKS.



*Fig. I.*

*Three-phase Generator, showing exciter direct driven on end of shaft.*

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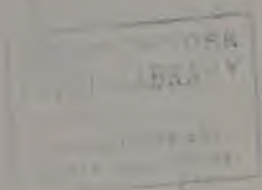


*Fig. II.*

*Armature of Three-phase Motor.*

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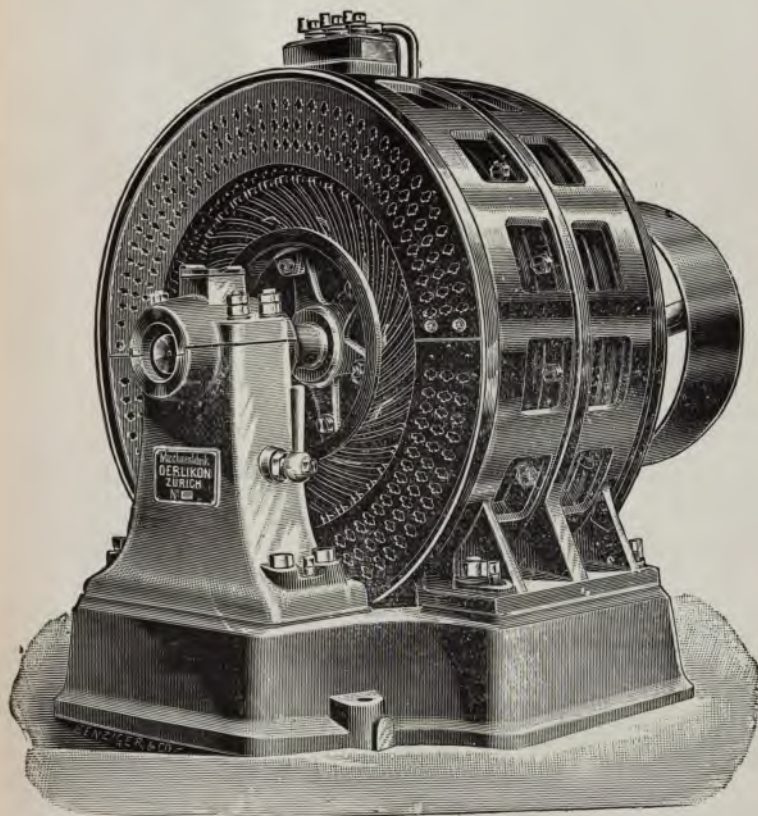
JOSEPH P. MORAN, Clerk of the Court.



WITNESSED my hand and the seal of the said Court, at the City of New York, this 1st day of January, 1908.

JOSEPH P. MORAN, Clerk of the Court.

Mr. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN  
MINES AND IRONWORKS.

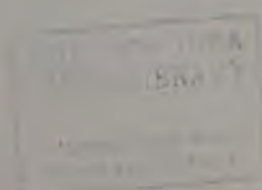


*Fig. III.*

12 B.H.P. Three-phase Motor.

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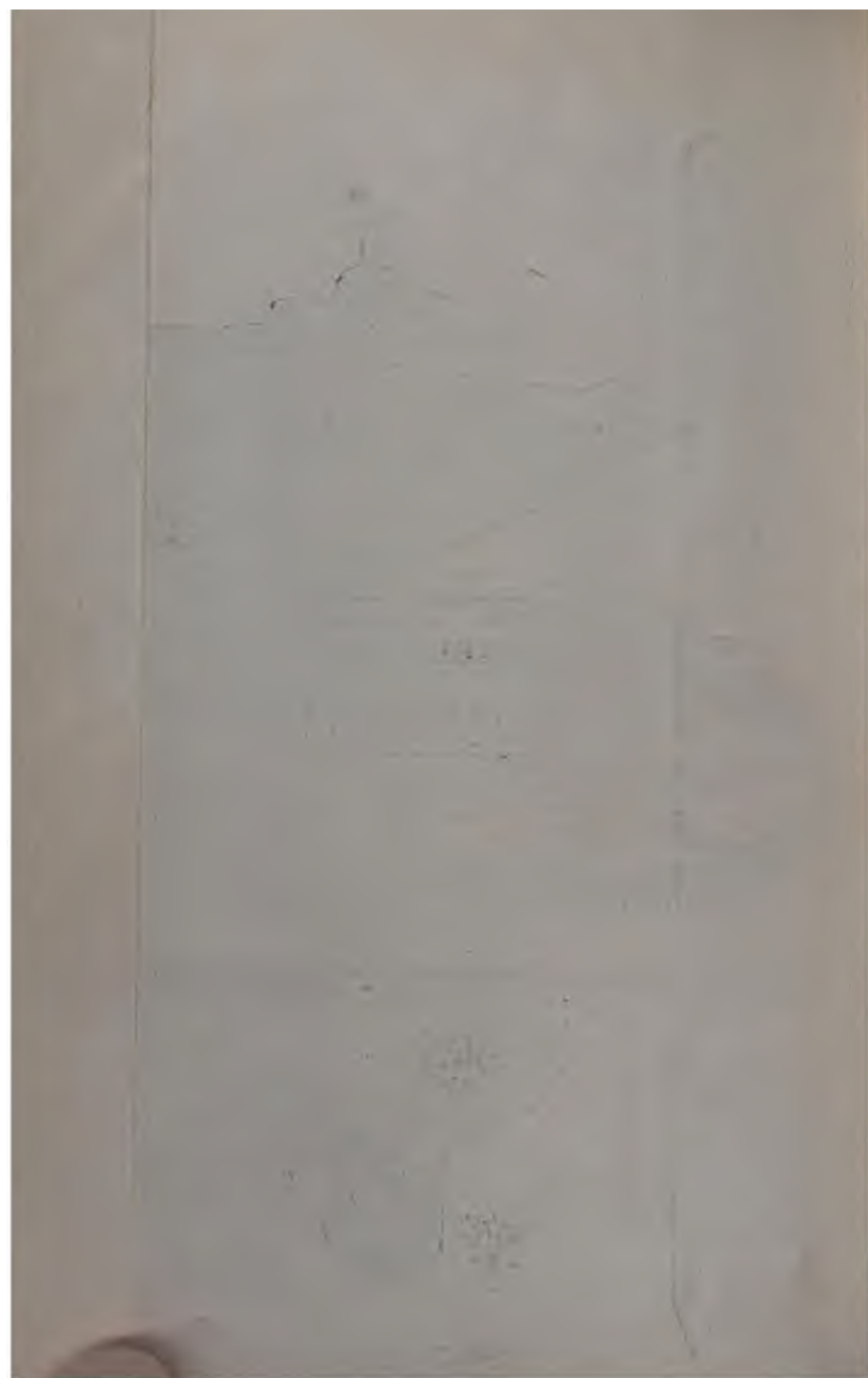
1871.

*Handwritten text, possibly a signature or date, located below the stamp.*

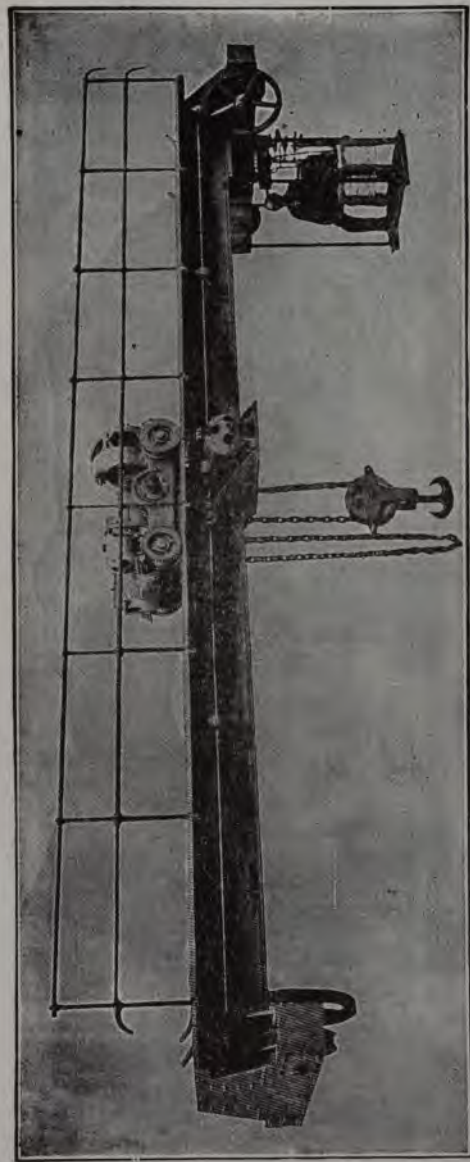
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Mr. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN MINES AND IRONWORKS.





MR. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN MINES AND IRONWORKS.

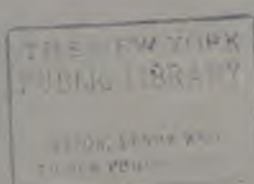


*Fig. V.*

PROCEEDINGS S. STAFF. INSTITUTE SESSION 1898 & 1899.

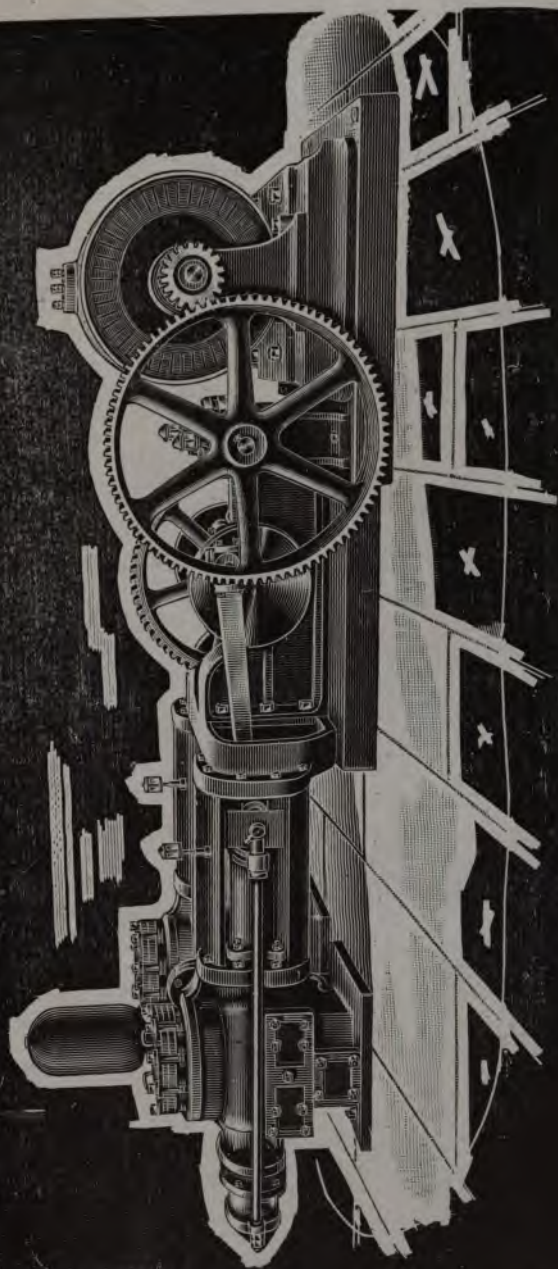
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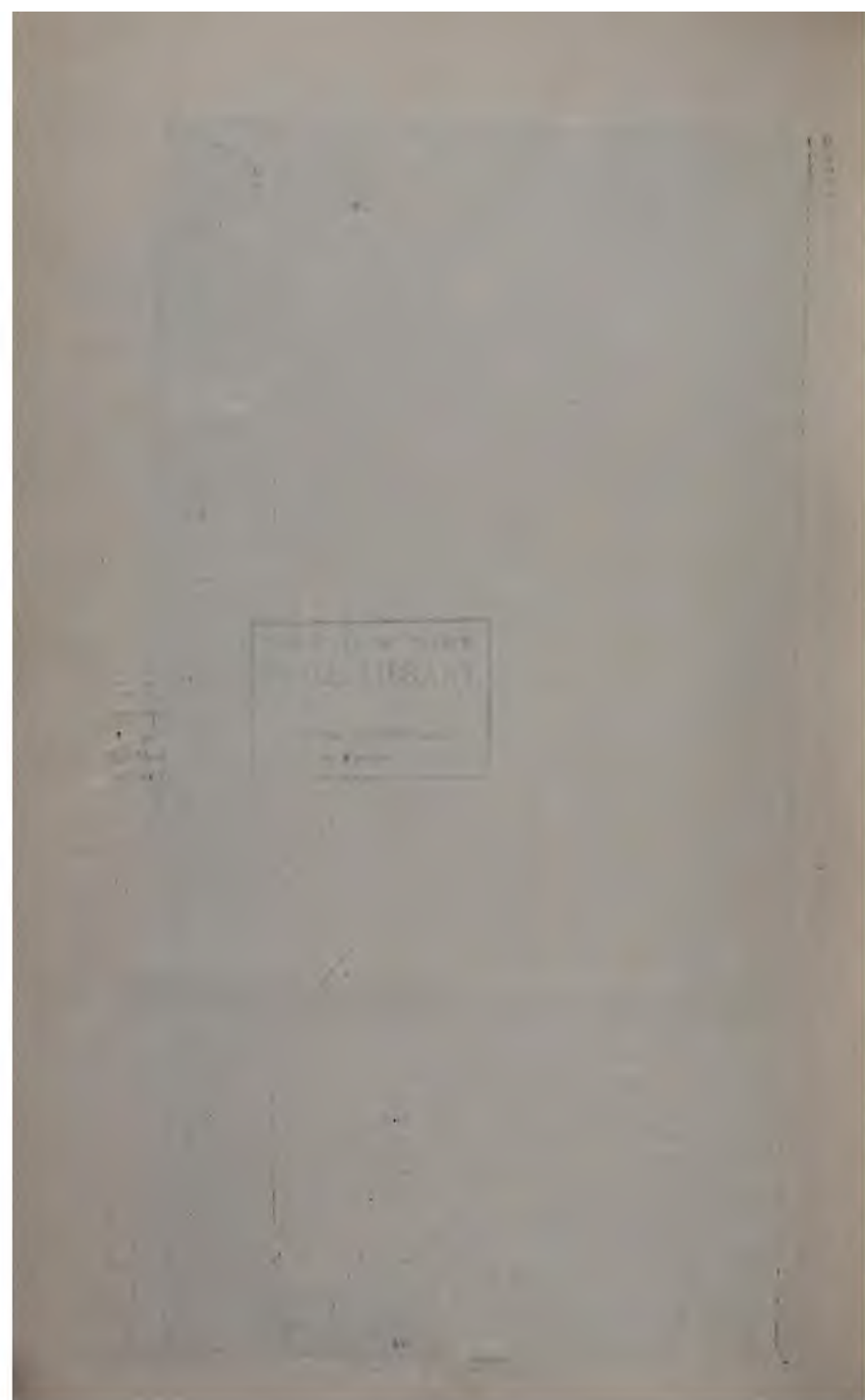
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MR. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN MINES AND IRONWORKS.

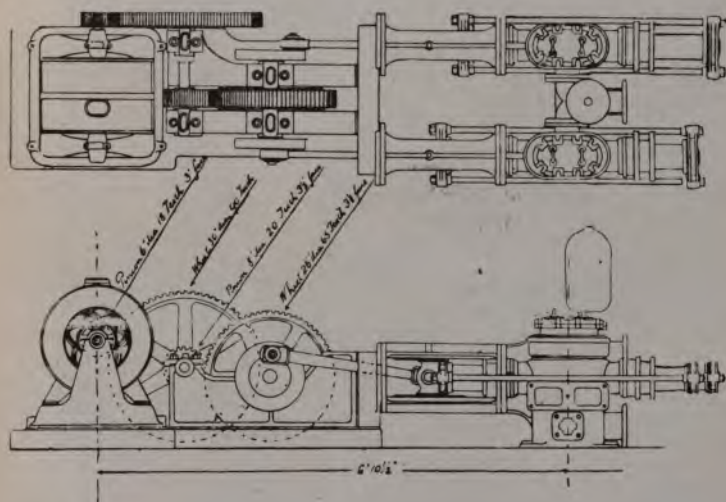


*Fig. VI.*

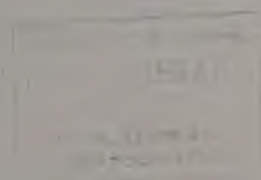
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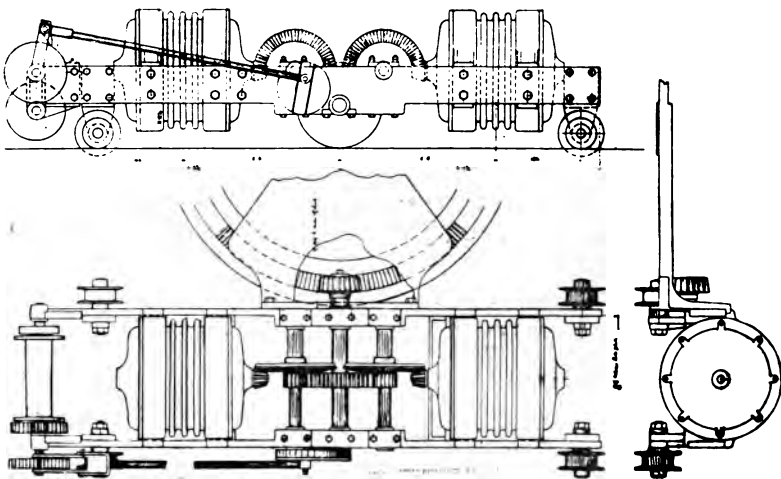
Mr. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN  
MINES AND IRONWORKS.



*Fig. VIa.*

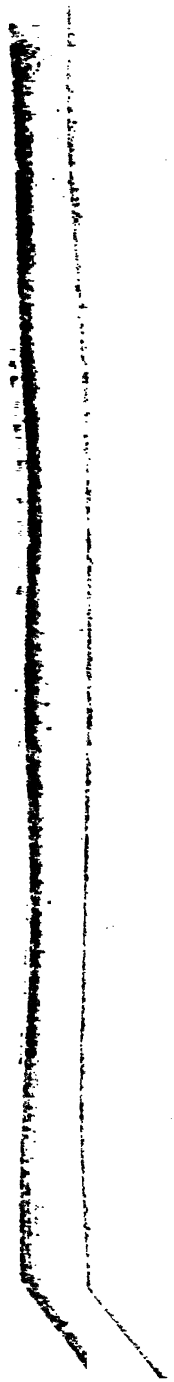


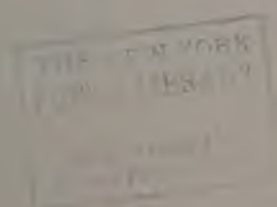
Mr. J. H. WHITTAKER'S PAPER ON ELECTRICITY IN  
MINES AND IRONWORKS.



*Fig. VII.*







MR. J. G. MARSHALL'S PAPER ON TRANSPORT IN AND ABOUT WORKS.



Steel Works' Travelling Crane.

PROCEEDINGS S. STAFF. INSTITUTE, SESSION 1898 & 1899.

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1. The first part of the document is a list of names and titles, including "The Hon. Mr. Justice" and "The Hon. Mr. Justice".



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